# Appendix F: Air Quality Technical Assessment

The definition of acronyms used in this Appendix are:

| | |
|---|---|
| AAQS | Ambient Air Quality Standards |
| APCD | Air Quality Control Division |
| AP-42 | EPA's compilation of emission factors |
| AQRV | Air Quality Related Values |
| BART | Best Available Retrofit Technology |
| BTEX | Benzene, toluene, ethylbenzene, and xylenes |
| CAAQS | Colorado Ambient Air Quality Standards |
| CAFO | Concentrated animal feeding operation |
| CAMx | Comprehensive Air Quality Model with Extensions |
| CH4 | Methane |
| CO | Carbon monoxide |
| CO2 | Carbon dioxide |
| CO2e | Carbon dioxide equivalent |
| km | Kilometer |
| µg/m3 | Micrograms per cubic meter |
| MMscf | Million standard cubic feet |
| mtpy | Metric tons per year |
| N | Nitrogen |
| N2O | Nitrous oxide |
| NO2 | Nitrogen dioxide |
| NOx | Oxides of nitrogen |
| NAAQS | National Ambient Air Quality Standards |
| PM | Particulate matter |
| PM2.5 | Particulate matter less than or equal to 2.5 microns in diameter |
| PM10 | Particulate matter with aerodynamic diameter of 10 microns or less |
| ppb | Parts per billion |
| ppm | Parts per million |
| PSD | Prevention of Significant Deterioration |
| S | Sulfur |
| SO2 | Sulfur dioxide |
| tpy | Tons per year (short) |

# Introduction

This air quality appendix provides an outline of the techniques that were employed in the environmental analysis process, and planning process, for the Kremmling Field Office (KFO). The PRMP/FEIS addresses future land and resource management options, and the potential environmental impacts that may result from each of those options, for approximately 377,900 surface acres and approximately 653,500 subsurface acres of mineral estate administered by the KFO in Jackson, Grand, and Summit counties in their entirety, and in portions of Eagle, Larimer and Routt Counties, Colorado. This combined acreage (surface acres and subsurface mineral estate) is being analyzed as the “Decision Area” for the purposes of this PRMP/FEIS. The “Planning Area” comprises all land ownerships in these counties within the boundaries of the Kremmling Field Office, totaling about 3.1 million surface acres and 2.2 million acres of federal mineral estate.  Under the PRMP/FEIS, approximately 91 percent of the Federal mineral estate in the Decision Area is available for oil and gas leasing. Approximately 27 percent of federal mineral estate in the Decision Area is leased for oil and gas.

Approximately 675 wells have been drilled in the Planning Areas since the early 1920s. Averaged over the past 90 years, this is approximately 7 to 8 wells per year. After internal and external scoping was conducted during the planning process, it was determined that a qualitative assessment for air resource impacts was appropriate for most management activities proposed in the DRMP/DEIS. A quantitative Emissions Inventory was developed to analyze the potential emissions associated with oil and gas activities and livestock grazing. Due to the relatively low level of fluid minerals development, and to the highly speculative nature of currently available data, including the lack of well location data, the BLM determined that a hypothetical Air Quality Modeling Assessment for the DRMP/DEIS would not provide useful, or accurate, predictive information for the public or for the decision-maker. When adequate data becomes available, such as during the project application stage, it may become necessary to require air quality modeling in order to assess the potential impacts during the National Environmental Policy Act (NEPA) environmental analysis process for future activities prior to authorization by the BLM.

Historically, there has been relatively little oil or gas development in the Planning Area; the underground geology of the area is not well understood. If, or when, exploration wells are drilled, more information will be known about the location, quality, and characteristics of the resources. The KFO has a Reasonably Foreseeable Development (RFD) Scenario that discusses the potential of up to 370 oil and gas wells (192 wells on Federal lands and 178 wells on fee lands) to be drilled over the next 20 years (BLM 2008r). The BLM determined that the preparation of an Emission Inventory would be the most appropriate assessment for air quality at this time. Detailed information is either unknown, or too speculative, to conduct a quantitative air quality impacts analysis (a Modeling Analysis). If, or when, activities are proposed for implementation under the Approved RMP (Approved Plan), and if air quality is determined to be an issue of concern during the environmental analysis process, a more detailed air quality analysis will be conducted, including, potentially, a more detailed Emissions Inventory or a Modeling Assessment. See Appendix X, Air Quality Management Plan for related information.

The BLM – Colorado is currently conducting a Colorado-wide oil and gas modeling study (CARMMS) that will include analyses for each BLM Field Office including the KFO. For this Study, oil and gas emissions increases projected out 10 years from year 2011 according to RFD and recent oil and gas development data will be modeled and impacts will be determined for each Field Office. Regional ozone and other pollutants and air quality related values (AQRVs) including visibility impacts will be evaluated in that Study. The Study should be completed in spring 2014. As future oil and gas development occurs in the KFO, the BLM Colorado plans to compare project-specific permitted levels of emissions to the KFO oil and gas emissions rates modeled in the regional study along with the corresponding modeling results to ensure that the BLM Colorado is permitting activities that stay within the acceptable modeled emissions analyzed in the cumulative air quality impacts study.

# Air Quality Management Framework

The basic framework for controlling air pollutants in the United States is mandated by the Clean Air Act (CAA), and its amendments, and by State air quality management programs. Federal and State air quality management programs have evolved using two distinct management approaches:

- **State Implementation Plan --** The first type of management approach is the State Implementation Plan (SIP) process of setting ambient air quality standards for acceptable exposure to air pollutants; conducting monitoring programs in order to identify locations experiencing air quality problems; and developing programs and regulations designed to reduce, or eliminate, those problems.
- **Hazardous Air Pollutants --** The second type of management approach involves the Hazardous Air Pollutant (HAP) regulatory process, which identifies specific chemical substances that are potentially hazardous to human health, and then sets emission standards in order to regulate the amount of those substances that can be released by individual commercial or industrial facilities, or by specific types of equipment.

Air quality programs based upon ambient air quality standards typically address air pollutants that are produced in large quantities by widespread types of emission sources, and that are of public health concern. In addition to pollutants for which there are adopted ambient standards, the SIP planning process is also used in order to address regional haze visibility issues. The industry-specific emission regulation approach is used currently to address air quality concerns of hazardous air pollutants and some ozone-depleting chemicals.

For the BLM, air quality and climate are the principle components of the BLM Air Resource Management Program. The program focuses on management of air resources, as well as on how they affect, and are affected by, other resource values and uses of the public lands.

Air quality is determined by the composition (chemical and physical) and concentration of atmospheric pollutants, meteorology, and terrain; it also includes noise considerations, smoke management, and visibility. The CAA currently identifies six nationally regulated air pollutants (called criteria pollutants) and 187 hazardous air pollutants, subject to change over time. For more information, visit: http://www.epa.gov/ttn/atw/pollsour.html. Activities, programs, and projects initiated by the BLM, as well as activities and projects initiated by external proponents, have the potential to impact air quality by emissions of these pollutants. The BLM analyzes the potential impacts of all Proposed Actions on air quality as part of its planning, environmental analysis, and decision-making processes.

Climate represents the long-term statistics of daily, seasonal, and annual weather conditions. Climate is the composite of generally prevailing weather conditions of a particular region throughout the year, averaged over a series of years (typically, 30 years). Climate is both a driving force and a limiting factor for biological, ecological, and hydrologic processes, and for resource management activities such as disturbed-site reclamation, wildland fire management, drought management, rangeland and watershed management, and wildlife habitat administration.

The BLM is responsible for ensuring that the activities, programs, and projects it undertakes or authorizes comply with all applicable laws, rules, regulations, policies, standards, and guidelines; including establishing conditions of approval (COAs) and stipulations in leases and permits. Under the Federal Land Policy and Management Act (FLPMA), the BLM is responsible for developing RMPs that provide for compliance with applicable pollution control laws, including State and Federal air, water, noise, or other pollution standards or implementation plans; and to manage the public lands in a manner that will protect the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archeological values. In addition, RMPs may also establish management goals and objectives for BLM-managed public lands, and their associated resources, which require managing activities in a manner designed to attain, or maintain, a higher standard of air quality than that required by the CAA.

## Criteria Pollutants

The U.S. Environmental Protection Agency (EPA) has established National Ambient Air Quality Standards (NAAQS) for six different pollutants, called criteria pollutants. Criteria pollutants include carbon monoxide (CO), nitrogen dioxide ($NO_2$), sulfur dioxide ($SO_2$), ozone ($O_3$), particulate matter ($PM_{10}$, $PM_{2.5}$), and lead (Pb). Federal ambient air quality standards are primarily based upon evidence of acute and chronic health effects that apply to outdoor locations to which the general public has access. The criteria pollutants are:

- **Carbon Monoxide --** Carbon monoxide is a colorless, odorless gas formed during incomplete combustion of organic compounds. The major sources of carbon monoxide are combustion processes, such as fuel combustion in motor vehicles and industrial processes, agricultural burning, prescribed burning, and wildfires. Carbon monoxide is a public health concern because it combines readily with hemoglobin in the blood, and, as a result, reduces the amount of oxygen transported to body tissues. Relatively low concentrations of carbon monoxide can significantly affect the amount of oxygen in the blood stream because carbon monoxide binds to hemoglobin 200 times to 250 times more strongly than does oxygen. The cardiovascular system and the central nervous system can be affected when 2.5 percent to 4.0 percent of the hemoglobin in the blood is bound to carbon monoxide rather than to oxygen. Usually, due to its low chemical reactivity and low solubility, indoor carbon monoxide levels are similar to outdoor levels.

- **Nitrogen Dioxide --** Nitrogen dioxide is a brownish red gas formed as an indirect product of combustion processes. Some nitrogen dioxide can be formed from nitrogen compounds contained in the combusted fuel; however, most is produced by high-temperature oxidation of nitrogen gas in the air. The dominant oxide of nitrogen produced during combustion is nitric oxide. Nitric oxide is converted fairly quickly into nitrogen dioxide by chemical reactions with atmospheric oxygen and ozone. Nitrogen dioxide is a respiratory and eye irritant, as well as a plant toxin. Nitrogen dioxide is also a precursor of photochemically generated ozone, nitric acid, and nitrate aerosols.

- **Sulfur Dioxide --** Sulfur dioxide is a colorless, but pungent, gas formed primarily by combustion of sulfur-containing compounds. Sulfur dioxide is a respiratory irritant, and undergoes chemical reactions that can form sulfuric acid and various sulfate aerosols.

- **Ozone --** Ozone is not released directly into the atmosphere. It forms as the result of complex chemical reactions that occur in sunlight. The chemical reactions that produce ozone involve a wide range of volatile organic compounds (VOCs) and oxides of nitrogen. VOCs and nitrogen oxides (the combination of nitric oxide and nitrogen dioxide) are the precursor emission products that form ozone. The atmospheric chemical reaction processes that produce ozone also produce chemically formed particulate matter and acidic compounds. Combustion processes, which produce nitrogen oxides, and evaporation of VOCs, are the major emission sources for organic compounds. Common combustion sources include: fuel combustion in motor vehicles; fuel combustion in industrial processes; agricultural burning; prescribed burning; and wildfires. Common evaporative sources of organic compounds include paints, solvents, liquid fuels, or liquid chemicals. Ozone is a strong oxidizing agent that reacts with a wide range of materials and biological tissues. It is a respiratory irritant that can result in acute and chronic impacts to the respiratory system. Recognized impacts include: reduced pulmonary function; pulmonary inflammation; increased airway reactivity; aggravation of existing respiratory diseases such as asthma, bronchitis, and emphysema; physical damage to lung tissue; decreased exercise performance; and increased susceptibility to respiratory infections. In addition, ozone is a necrotic agent that significantly damages leaf tissues of crops and natural vegetation. Ozone also damages many materials by acting as a chemical oxidizing agent. Usually, due to its photochemical activity, indoor ozone levels are much lower than outdoor levels.

- **Particulate Matter --** The major emission source categories for suspended particulate matter include: combustion sources, such as fuel combustion in motor vehicles and industrial processes, agricultural burning, prescribed burning, and wildfires; aerosols; industrial grinding and abrasion processes; soil disturbance by construction, agricultural and forestry equipment, recreational vehicles, or other vehicles and equipment; mining and other mineral extraction activities; and wind erosion resulting from exposed soils and sediments. Suspended particulate matter is also formed by atmospheric chemical reactions.

  Suspended particulate matter represents a diverse mixture of solid and liquid material having size, shape, and density characteristics that allow the material to remain suspended in the air for meaningful time periods. The physical and chemical composition of suspended particulate matter is highly variable, resulting in a wide range of public health concerns. Many components of suspended particulate matter are respiratory irritants. Some components, such as crystalline or fibrous minerals, are primarily physical irritants. Other components are chemical irritants, such as sulfates, nitrates, and various organic chemicals. Suspended particulate matter also can contain compounds, such as heavy metals and various organic compounds that are systemic toxins or necrotic agents. Suspended particulate matter or compounds adsorbed on the surface of particles can also be carcinogenic or mutagenic chemicals. Public health concerns associated with suspended particulate matter focus on the particle size ranges likely to reach the lower respiratory tract or the lungs. Inhalable particulate matter ($PM_{10}$) represents particle size categories that are likely to reach either the lower respiratory tract or the lungs after being inhaled. Fine particulate matter ($PM_{2.5}$) represents particle size categories likely to penetrate to the lungs after being inhaled. (The “10” in $PM_{10}$ and the “2.5” in $PM_{2.5}$ are not upper size limits. The numbers refer to the particle size range collected with 50 percent mass efficiency by certified sampling devices; larger particles are collected with lower efficiencies, and smaller particles are collected with higher efficiencies.)

  In addition to public health impacts, suspended particulate matter results in a variety of material damage and nuisance impacts, including abrasion; corrosion, pitting, and other chemical reactions on material surfaces; soiling; and transportation hazards due to visibility impairment.

- **Lead --** Lead is a toxic metal that can cause learning disabilities and damage to the kidneys and brain. Atmospheric lead compounds occur, primarily, as a component of suspended particulate matter. Since the phase-out of lead additives in most gasoline, the dominant source of lead in atmospheric particles in the United States has become industrial facilities, such as lead smelters, and dust from deteriorating lead-based paints.

## Colorado and National Ambient Air Quality Standards

Colorado has adopted State ambient air quality standards that are, generally, equal to current or former Federal standards. Colorado has adopted a 3-hour sulfur dioxide standard that is more stringent than the comparable Federal standard. Table F-2.1, Colorado and National Ambient Air Quality Standards, summarizes current Federal and Colorado ambient air quality standards. (*NOTE: Since this table was created, the EPA has promulgated some additional standards: an additional 1-hour standard for $NO_2$, which is 189 ug/$m^3$; an additional 1-hour standard for $SO_2$, which is 196 ug/$m^3$; also, the $PM_{2.5}$ annual standard is now 12 ug/$m^3$*.)

Air pollutants covered by State and Federal ambient air quality standards can be categorizedby the nature of their toxic effects, such as:

- irritants, such as ozone, particulate matter, nitrogen dioxide, sulfur dioxide, sulfate particles, and hydrogen sulfide, that affect the respiratory system, eyes, mucous membranes, and the skin;
- asphyxiants, such as carbon monoxide and nitric oxide, that displace oxygen or interfere with oxygen transfer in the circulatory system, thereby affecting the cardiovascular and central nervous system;
- necrotic agents, such as ozone, nitrogen dioxide, and sulfur dioxide, that directly cause cell death; or
- systemic poisons, such as lead particles, that affect a range of tissues, organs, and metabolic processes.

**Table F-2.1 National Ambient Air Quality Standards (NAAQS), Colorado Ambient Air Quality Standards (CAAQS), and PSD Significant Monitoring Concentrations**

| Criteria Pollutant | Avg. Period | Primary Standard ($\mu g/m^3$ [ppm/ppb]) | Secondary Standar | Additional Standsards | PSD Significant Monitoring Concentration |
|---|---|---|---|---|---|
| | | NAAQS | NAAQS | CAAQS | |
| CO | 1-hour | 40,000 [35ppm] | None | NA | NA |
| CO | 8-hour | 10,000 [9ppm] | None | NA | 575 $ug/m^3$ |
| $NO_2$ | 1-hour | 189 [100ppb] | NA | NA | NA |
| $NO_2$ | Annual | 100 [53ppb] | 100 [53ppb] | NA | 14 ug/m3 |
| $PM_{10}$ | 24-hour | 150 | 150 | NA | 10 ug/m3 |
| $PM_{2.5}$ | 24-hour | 35 | 35 | NA | 4 ug/m3 |
| $PM_{2.5}$ | Annual | 15 | 15 | NA | NA |
| $SO_2$ [e] | 1-hour | 196 [75ppb] | NA | NA | NA |
| $SO_2$ [f] | 3-hour | NA | 1300 [.5ppm] | 700 ug/m3 | NA |
| $SO_2$ [g] | 24-hour | NA | NA | NA | 13 ug/m3 |
| $SO_2$ [g] | Annual | 80 [0.030] | NA | NA | NA |
| Ozone | 8-hour | .075 ppm | .075 ppm | NA | 100 tpy VOCs or Nox |

| | | | | | |
|---|---|---|---|---|---|
| Lead | rolling 3-month | .15 ug/m3 | .15 ug/m3 | NA | NA |
| Lead | 3-month | NA | NA | NA | .1 ug/m3 |
| Fluorides | 24-hour | NA | NA | NA | .25 ug/m3 |
| Total Reduced Sulfur | 1-hour | NA | NA | NA | .2 ug/m3 |
| Reduced Sulfur Compounds | 1-hour | NA | NA | Na | 10 UG/M3 |
| **The significant monitoring concentrations (de minimis levels) apply only to new sources and modifications subject to PSD review (see Regulation No. 3, Part D, section VI.) | | | | | |

CAAQS = Colorado Ambient Air Quality Standards

$\mu g/m^3$ = micrograms per cubic meter

N/A = not applicable

NAAQS = National Ambient Air Quality Standards

[a] For short-term (non-annual) averaging times, compliance with the CO, $PM_{10}$, and $SO_2$ NAAQS is based on the highest-second-highest (H2H) short-term concentration, while compliance with the short-term $PM_{2.5}$ and $NO_2$ NAAQS is based on the highest 3-year average eighth-highest short-term concentration. Short-term modeled concentrations reported here are highest-second-highest for CO, $PM_{10}$, and $SO_2$, and highest-eighth-highest for $PM_{2.5}$ and $NO_2$. Annual (long-term) modeled concentrations are highest concentrations which are required for an annual average NAAQS compliance demonstration.

[b] The 1-hour $NO_2$ background concentration was not added to the modeled concentration. February 22, 2010 USEPA guidance describes identification of the 3-year average of the eighth-highest modeled concentration on a receptor-by-receptor basis (USEPA 2010c). Inclusion of background concentration is not included in the procedure for comparing AERMOD modeling results with the 1-hour $NO_2$ NAAQS.

[c] $PM_{2.5}$ and $PM_{10}$ modeling results are shown for Alternatives B, C, and D fugitive dust emission rates (which are identical) and for Alternative A non-fugitive dust emission rates.

[d] Due to 1-hour $NO_2$, 24-hour $PM_{2.5}$, and 1-hour $SO_2$ NAAQS standard formats that use a three-year average to determine compliance, only one total concentration is reported for the three-year modeling period.

[e] The new 1-hour $SO_2$ standard became effective on August 23, 2010. To comply with the 1-hour $SO_2$ standard, the three-year average of the annual 99th percentile of the 1-hour daily maximum concentration must be less than or equal to 195.5 $\mu g/m^3$ (75 ppb).

[f] As of August 23, 2010, this standard transitioned from a primary standard (protecting human health) to a secondary standard (protecting environment) at the federal level. However, state air quality agencies have discretion to continue enforcing this standard as a primary standard. The 3-hour standard will become obsolete at the federal level once attainment/nonattainment designations under the new 1-hour $SO_2$ standard are promulgated by USEPA.

[g] The 24-hour and annual standard will become obsolete at the federal level once attainment/nonattainment designations under the new 1-hour $SO_2$ standard are promulgated by USEPA.

# Hazardous Air Pollutants

Air quality programs based upon the regulation of other hazardous substances typically address chemicals used, or produced, by limited categories of industrial facilities. Programs regulating hazardous air pollutants focus on substances that alter or damage the genes and chromosomes in cells (mutagens); substances that affect cells in ways that can lead to uncontrolled cancerous cell growth (carcinogens); substances that can cause birth defects or other developmental abnormalities (teratogens); substances with serious acute toxicity effects; and substances that undergo radioactive decay processes (resulting in the release of ionizing radiation). Federal air quality management programs for hazardous air pollutants focus on setting emission limits for particular industrial processes rather than on setting ambient exposure standards. Federal emission standards for hazardous air pollutants have been promulgated as National Emission Standards for Hazardous Air Pollutants (NESHAP) and as Maximum Achievable Control Technology (MACT) standards. The Federal MACT standard for mercury emissions from coal-fired power plants represents an example of such hazardous air pollutant control programs. The NESHAP and MACT standards are implemented through State and Federal air quality permit programs. Colorado Air Pollution Control Division (APCD) Regulation 8 adopts Federal NESHAP and MACT standards by reference, and includes additional requirements for the State asbestos control program.

# Visibility Impairment

The EPA, the BLM, the US Forest Service (USFS), the National Park Service (NPS), the U.S. Fish and Wildlife Service (USFWS), and regional associations of State Air Quality Management Agencies operate the Inter-agency Monitoring of Protected Environments (IMPROVE) program. The IMPROVE program monitors visibility conditions and particulate matter concentrations in, or near, Class I Areas across the country. Some of the IMPROVE sites also document visibility conditions with remotely operated cameras. There are six IMPROVE monitoring locations in Colorado; three of which are in, or near, the Planning Area. The NPS operates one Monitoring Station on the east side of Rocky Mountain National Park. The USFS operates one Monitoring Station at Buffalo Pass (south end of the Mount Zirkel Wilderness), and one Monitoring Station at the Aspen Mountain Ski Area (east of the Maroon Bells-Snowmass Wilderness).

## Atmospheric Deposition Constituents

Two separate Air Quality Monitoring Programs are being used to monitor atmospheric deposition of various compounds. The Programs originated as acid deposition monitoring programs, but they have expanded to include monitoring of other compounds. The EPA Clean Air Status and Trends Network (CASTNET) operates as a dry deposition monitoring program. There are three CASTNET monitoring sites in Colorado: Rocky Mountain National Park, Gothic, and Mesa Verde National Park. The CASTNET monitoring site in Rocky Mountain National Park is not co-located with the IMPROVE site in the Park. The National Atmospheric Deposition Program/National Trends Network (NADP/NTN) program provides wet deposition monitoring focused on acid deposition issues. A mercury deposition monitoring program was integrated into the NADP/NTN program in 1996, although it does not operate at all NADP/NTN sites. Nationally, there are more than 250 sites in the NADP/NTN network, with 19 sites in Colorado. Some of the NADP/NTN sites are either co-located, or located near, CASTNET or IMPROVE monitoring sites.

## Greenhouse Gases

Greenhouse gases (GHGs) are compounds in the atmosphere that absorb infrared radiation and re-radiate a portion of that back toward the Earth's surface, thereby trapping heat and warming the Earth's atmosphere. The most important naturally occurring GHG compounds are carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), ozone ($O_3$), and water vapor ($H_2O$). Carbon dioxide, methane, and nitrous oxide are produced naturally by respiration and other physiological processes of plants, animals, and microorganisms; by the decomposition of organic matter; by volcanic and geothermal activity; by naturally occurring wildfires; and by natural chemical reactions in soil and water. Ozone is not released directly by natural sources. It forms during complex chemical reactions in the atmosphere among organic compounds and nitrogen oxides in the presence of ultraviolet radiation. Water vapor is a strong GHG, although its concentration in the atmosphere is primarily a result of (not a cause of) changes in surface and lower atmospheric temperature conditions.

Although naturally present in the atmosphere, concentrations of carbon dioxide, methane, and nitrous oxide are also affected by emissions from industrial processes, transportation technology, urban development, agricultural practices, and other human activity. The Intergovernmental Panel on Climate Change (IPCC) estimates the following changes in global atmospheric concentrations of the most important GHGs (IPCC 2001, 2007):

- atmospheric concentrations of carbon dioxide have risen from a pre-industrial background of 280 parts per million by volume (ppm) to 379 ppm in 2005;
- atmospheric concentrations of methane have risen from a pre-industrial background of about 0.70 ppm to 1.774 ppm in 2005; and

- atmospheric concentrations of nitrous oxide have risen from a pre-industrial background of .270 ppm to 0.319 ppm in 2005.

The IPCC has concluded that these changes in atmospheric composition are almost entirely the result of human activity, not the result of changes in natural processes that produce or remove these gases (IPCC 2007).

Carbon dioxide, methane, and nitrous oxide have atmospheric residence times ranging from about a decade to more than a century. Several other important GHG compounds with long atmospheric residence times are produced almost entirely by various industrial processes. These include sulfur hexafluoride ($SF_6$), and a wide range of fluorinated hydrocarbons (HFCs). Fluorinated compounds typically have atmospheric residence times ranging from a few decades to thousands of years. The overall global warming potential of GHG emissions is presented typically in terms of carbon dioxide equivalents ($CO_2e$), using equivalency factors developed by the IPCC. The IPCC has published sets of $CO_2e$ factors as part of its periodic climate change assessment reports issued in 1995, 2001, and 2007.

Of these pollutants, carbon dioxide, methane, and nitrous oxide are commonly emitted by oil and gas sources, while the remaining three GHGs are emitted in extremely small quantities, or are not emitted at all. As the major component of natural gas, $CH_4$ emissions resulting from oil and gas exploration, production, and transportation are considerable.

Aggregate GHG emissions are discussed in terms of carbon dioxide equivalent ($CO_2e$). Each GHG has a global warming potential (GWP). As defined by the EPA, the GWP provides a "ratio of the time-integrated radiative forcing from the instantaneous release of one kilogram of a trace substance relative to that of one kilogram of $CO_2$" (GPO 2010). In other words, the GWP accounts for the intensity of each GHG's heat trapping effect and its longevity in the atmosphere. The GWP provides a method to quantify the cumulative impact of multiple GHGs released into the atmosphere by calculating $CO_2e$ for the GHGs. The EPA's GWPs are provided in **Error! Reference source not found.** F-2.2, and were determined on a 100-year basis. These GWPs are established in EPA regulations in Title 40 of the Code of Federal Regulations (CFR) Part 98.

**Table F-2.2 : GHGs Reported to EPA and Global Warming Potentials**

| Air Pollutant | Chemical Symbol or Acronym | Global Warming Potential |
|---|---|---|
| Carbon dioxide | $CO_2$ | 1 |
| Methane | $CH_4$ | 21 |
| Nitrous oxide | $N_2O$ | 298 |
| Hydrofluorocarbons | HFCs | Varies |
| Perfluorocarbons | PFCs | Varies |
| Sulfur hexafluoride | SF6 | 23,900 |

Sources: GPO 2009; GPO 2010, Table A-1.

To date, the EPA has not mandated stationary source GHG emission reductions or set NAAQS for these pollutants. The EPA does require certain GHG emission sources, and some GHG suppliers, to report GHG emissions. Beginning in 2011, large stationary sources of GHGs are required to obtain Air Quality Permits from local, State, or Federal air quality agencies (GPO 2010f).

The EPA estimates that national GHG emissions in 2006 were 6,801,812,000 tons $CO_2e$ (EPA 2008). National GHG emissions in 2006 represented a 14 percent increase from estimated 1990 national GHG emissions (5,964,166,000 tons $CO_2e$). The EPA categorized the major economic sectors contributing to U.S. emissions of GHG compounds as:

- electric power generation (34.5 percent);
- transportation (28.6 percent);
- industrial processes (19.9 percent);
- agriculture (7.7 percent);
- commercial land uses (5.7 percent); and
- residential land uses (3.6 percent).

# Air Quality Permit Programs

The CAA establishes a basic Air Quality Permit Program for industrial emission sources. Key elements of the Federal requirements include pre-construction permits [new source review and prevention of significant deterioration (PSD)] and annual Operating Permits (Title V). Separate reconstruction requirements have been established for non-attainment pollutants and for attainment pollutants. The Federal New Source Review (NSR) Program applies in non-attainment areas to the applicable non-attainment pollutants. A key element of the NSR Program is a requirement to implement emission offsets so that a new source of emissions will not result in a net increase in non-attainment pollutant emissions for the non-attainment area. The Federal PSD Program applies to attainment pollutants. Key elements of the PSD Program include potential requirements for pre-construction and post-construction ambient air quality monitoring; the establishment of baseline ambient air quality levels maximum cumulative pollutant increments allowed above those baseline levels; the evaluation of proposed emission sources in order to determine their consumption of available PSD pollutant increments; and the evaluation of visibility impacts in designated Class I Wilderness Areas, National Parks, and National Monuments. The Federal operating permit program is referred to as the Title V Permit Program, which establishes reporting and record-keeping requirements designed to ensure that conditions imposed by pre-construction permits are being met.

States, in general, have assumed primary responsibility for enforcing most Federal permit requirements, with the EPA exercising a formal review and oversight responsibility. Some States, including Colorado, have separate air permit programs authorized by State legislation. State air permit requirements typically cover emission sources that are smaller than those subject to Federal permit requirements. In most cases, including Colorado, State air permit programs have been integrated with Federal NSR, PSD, and Title V requirements, to provide a consolidated permit program. Under consolidated permit programs, basic State permit requirements apply to all sources that are not specifically exempted. Additional NSR and PSD program requirements, including EPA review of the permit, become applicable if sources exceed various size or emission thresholds. The owners and operators of emission sources are the parties responsible for obtaining required air permits.

The Colorado Air Pollution Control Commission (APCD) administers State and Federal air permit programs in Colorado through the Colorado Air Pollution Control Division (APCD) of the Colorado Department of Public Health and Safety (CDPHE). In addition to permit programs for stationary emission sources, the Colorado APCD administers a State permit program that regulates open burning and prescribed fires. Colorado APCD Regulation 9 establishes separate permit programs for open burning and prescribed fires. The Colorado APCD administers the prescribed fire permit program throughout the State and administers the Open Burn Permit Program in most Counties. Administration of the Open Burn Permit Program has been delegated to some Counties (Boulder, Eagle, El Paso, Grand, Jefferson, Lake, Larimer, Los Animas, Mesa, Pueblo, Routt, Summit, and Weld). Prescribed fires smaller than *de minimis* thresholds set by Regulation 9 qualify for open burn permits.

State regulations define significant users of prescribed fire as local, State, or Federal agencies, or private landowners, that manage or own more than 10,000 acres of grassland or forest land in Colorado, and that plan to use prescribed fires, broadcast burns, or pile burns which are expected to generate more than 10 tons of $PM_{10}$ in a calendar year. Significant users of prescribed fire are required to submit Prescribed Fire Plans and obtain Prescribed Fire Permits. Prescribed Fire Plans submitted by significant users of prescribed fire can cover a period of up to 10 years, and are subject to public review and comment. The BLM, the USFS, the NPS, and the USFWS have all received approval for their Prescribed Fire Plans.

# Prevention of Significant Deterioration

The Federal CAA requires a planning program with the goal that all areas of the country achieve the Federal ambient air quality standards within various specified timeframes. For attainment areas that already meet the Federal ambient air quality standards, the Federal PSD Permit Program established a 3-tier classification defining the extent to which baseline air quality conditions can be degraded. Class I Areas have the smallest allowable air quality deterioration limits. Class II Areas allow greater deterioration of air quality, but these areas must maintain air quality conditions better than the Federal air quality standards. Class III Areas allow deterioration of air quality to the level of the Federal ambient air quality standards. The PSD program cumulative pollutant increments above baseline conditions have been established only for $NO_2$, $SO_2$, and $PM_{10}$. The incremental increases allowed for specific pollutants in Class I and Class II Areas are summarized in Table F-2.3, PSD Increments.

**Table F-2.3: PSD Increments**

| Pollutant | Averaging Period | Class II PSD Increments | Class I PSD Increments |
|---|---|---|---|
| NO2 | Annual2 | 25 | 2.5 |
| PM10 | 241<br>Annual | 30<br>17 | 8<br>4 |
| PM2.5 | 24<br>Annual | 9<br>4 | 2<br>1 |
| SO2 | 31<br>241<br>Annual2 | 512<br>91<br>20 | 25<br>5<br>2 |

[1] No more than one exceedance per year.
[2] Annual arithmetic mean.
[3] Average of annual fourth-highest daily maximum 8-hour average.
[4] Category III Incremental standards (increase over established baseline).

## Regional Haze Regulations

The CAA requires the EPA to protect visibility conditions in the Class I Areas established under the PSD program, unless the responsible land management agency determines that visibility is not an important air quality value for a particular area. The CAA also requires the development of programs designed to remedy existing visibility impairment in Class I Areas if that visibility impairment results from human-made air pollution. The EPA has identified two general types of visibility impairment at Class I Areas: 1) impairment due to smoke, dust, colored gases, or layered haze attributable to a single stationary emission source or a small group of emission sources; and 2) impairment due to widespread, regionally homogeneous haze resulting from the cumulative emissions of varied emission sources in a region. The PSD permit program addresses visibility impairment from nearby stationary emission sources. Regional haze impacts resulting from cumulative emissions in a region are being addressed through new SIP planning requirements. Colorado submitted a SIP Amendment to the EPA in December of 2007, to address regional haze issues. One of the components of the regional haze SIP is implementation of best available retrofit technology (BART) emission controls on certain categories of existing stationary emission sources, including power plants, cement kilns, and industrial boilers, that were built prior to 1977, if their emissions are reasonably expected to contribute to visibility degradation in Class I Areas. The CAA established an initial list of 158 Class I Areas comprised, primarily, of Wilderness Areas, National Parks, and National Monuments. Five Native American tribal areas have subsequently been added to the list of Class I Areas. The remainder of the country is designated as Class II Areas. No areas have been designated as Class III Areas under the PSD Program. One element of the PSD Permit Program is a review of the extent to which a proposed emission source will impair visibility conditions in Class I Areas.

## Clean Air Act Conformity Requirements

Section 176(c) of the CAA requires Federal agencies to ensure that actions undertaken in non-attainment or maintenance areas are consistent with the CAA, and with federally enforceable Air Quality Management Plans. The EPA has promulgated separate rules that establish conformity analysis procedures for highway and mass-transit projects (40 CFR Part 93, Subpart A) and for other (general) Federal agency actions (40 CFR Part 93, Subpart B). General conformity requirements are, potentially, applicable to many Federal agency actions, although they apply only to those aspects of an action that involve ongoing Federal agency responsibility and control over direct or indirect sources of air pollutant emissions when those actions occur within non-attainment or maintenance areas.

The general conformity rule establishes a process that is intended to demonstrate that the proposed Federal action:

- will not cause, or contribute to, new violations of Federal air quality standards;
- will not increase the frequency or severity of existing violations of Federal air quality standards; and
- will not delay the timely attainment of Federal air quality standards.

The general conformity rule applies to Federal actions occurring in non-attainment or maintenance areas when the net change in total direct and indirect emissions of non-attainment pollutants or their precursors exceeds specified thresholds. The emission thresholds that trigger the requirements of the conformity rule are called *de minimis* levels. Emissions associated with stationary sources that are subject to permit programs incorporated into the SIP are not counted against the *de minimis* threshold. The CAA general conformity *de minimis* threshold for $PM_{10}$ maintenance areas is 100 tons of $PM_{10}$ emissions per year.

Compliance with the conformity rule can be demonstrated in several ways. Compliance is presumed if the net increase in direct and indirect emissions resulting from a Federal action would be less than the relevant *de minimis* level. If net emissions increases exceed the relevant *de minimis* value, a formal conformity determination process must be followed. Federal agency actions subject to the general conformity rule cannot proceed until there is a demonstration of consistency with the SIP through one of the following mechanisms:

- by dispersion modeling analyses demonstrating that direct and indirect emissions resulting from the Federal action will not cause, or contribute to, violations of Federal ambient air quality standards;
- by showing that direct and indirect emissions resulting from the Federal action are specifically identified and accounted for in an approved SIP;
- by showing that direct and indirect emissions associated with the Federal agency action are accommodated within emission forecasts contained in an approved SIP;
- by showing that emissions associated with future conditions will not exceed emissions that would occur from a continuation of historical activity levels;
- by arranging emission offsets to fully compensate for the net emissions increase associated with the action;
- by obtaining a commitment from the relevant air quality management agency to amend the SIP to account for direct and indirect emissions resulting from the Federal agency action; or
- in the case of regional water or wastewater projects, by showing that any population growth accommodated by such projects is consistent with growth projections used in the applicable SIP.

Dispersion modeling analyses can be used to demonstrate conformity only in the case of primary pollutants such as carbon monoxide or directly emitted $PM_{10}$. Modeling analyses cannot be used to demonstrate conformity for ozone because the available modeling techniques, generally, are not sensitive to site-specific emissions. No portions of the Planning Area have any Federal non-attainment or maintenance designations.

# Ambient Air Quality

Existing air quality data for the Planning Area is summarized in Chapter 3, Affected Environment. The available data indicate that State and Federal ambient air quality standards for criteria pollutants are not exceeded at existing monitoring locations.

Based upon the BLM's request, the CDPHE provided background air quality data to be used in the Air Quality Assessment for the DRMP/DEIS (Chick 2008). Appropriate background concentrations were provided for areas close to Walden, Colorado, where a portion of the development potential exists. Table F-3.1 lists the background concentrations provided by the CDPHE. Ambient background concentrations demonstrate that the entire Planning Area is in attainment for all applicable NAAQS.

**Table F-3.1 Background Ambient Air Quality Concentrations**

| Pollutant | Averaging Period | Measured Background Concentration | Basis for background concentration |
|---|---|---|---|
| $PM_{10}$ | 24-hr (2$^{nd}$ Max)<br>Annual | 23 µg/m$^3$<br>11 µg/m$^3$ | Colowyo Axial, West Site,<br>1997 to1998 |
| $PM_{10}$ | 24-hr (2$^{nd}$ Max)<br>Annual | 56 µg/m$^3$<br>30 µg/m$^3$ | Rifle, Garfield County. (2006 data) |
| $SO_2$ | 3-hr (2$^{nd}$ Max)<br>24-hr (2$^{nd}$ Max)<br>Annual | 0.009 ppm (23.98 µg/m$^3$)<br>0.005 ppm (13.32 µg/m$^3$)<br>0.002 ppm (5.33 µg/m$^3$) | Unocal, 1983 to 1984 |
| $SO_2$ | 1-hr (99$^{th}$ Percentile)<br>3-hr (2$^{nd}$ Max)<br>24-hr (2$^{nd}$ Max)<br>Annual | 0.031 ppm (80.8 µg/m$^3$)<br>0.026 ppm (66.6 µg/m$^3$)<br>0.013 ppm (34.6 µg/m$^3$)<br>0.002 ppm (5.3 µg/m$^3$) | Colorado College, Colorado Springs, El Paso County. (2005-2006) |

**Table F-3.1 Background Ambient Air Quality Concentrations**

| Pollutant | Averaging Period | Measured Background Concentration | Basis for background concentration |
|---|---|---|---|
| $NO_2$ | Annual | 0.005 ppm (3.83 µg/m$^3$) | Rural default based on Encana Near Parachute Creek, 2007 |
| $NO_2$ | 1-hr (Max) | 0.037 ppm (70.75 µg/m3) | Holcim/Golden (2005-2006) |
| CO | 1-hr (2$^{nd}$ Max)<br>8-hr (2$^{nd}$ Max) | 1 ppm (1,165 µg/m$^3$)<br>1 ppm (1,165 µg/m$^3$) | Rural default based on American Soda, Piceance 2003 to 2004 |
| $PM_{2.5}$ | 98$^{th}$ Percentile<br>Annual | 16 µg/m$^3$<br>6 µg/m$^3$ | Rural default based on Chatfield State Park, 2006 |
| Ozone | 1-hr (2$^{nd}$ Max)<br>8-hr (4$^{th}$ Max) | 0.058 ppm (116 µg/m$^3$)<br>0.053 ppm (106 µg/m$^3$) | Golden Energy Florence, 2005 to 2006 |
| Ozone | 1-hr (2$^{nd}$ Max)<br>8-hr (4$^{th}$ Max) | 0.088 ppm (176 µg/m$^3$)<br>0.075 ppm (150 µg/m$^3$) | Rocky Mountain National Park, 2004 to 2006 |

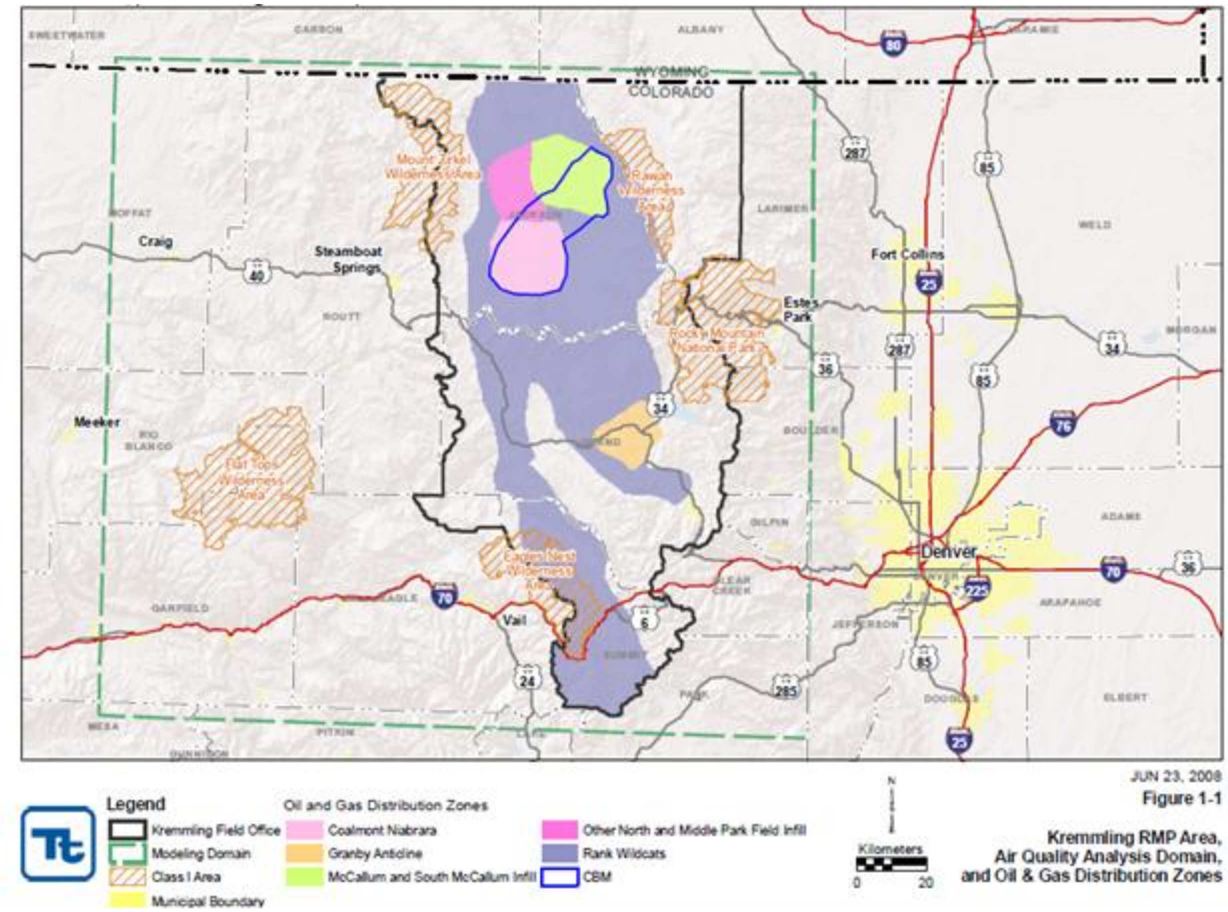
# Class I Areas

There are 12 PSD program Class I visibility protection areas in Colorado. Five of Colorado's Class I visibility protection areas are in, or close to, the Planning Area: Rocky Mountain National Park, the Mount Zirkel Wilderness, the Rawah Wilderness, the Eagles Nest Wilderness, and the Flat Tops Wilderness. The Rawah Wilderness Area is located completely in the Planning Area, while Rocky Mountain National Park and the Eagles Nest and Mount Zirkel Wilderness Areas have a portion of the Class I PSD area located in the Planning Area. Table F-3.2 lists the distance and location to the applicable Class I PSD areas, which are approximated from the center of the Planning Area. Figure F-3.1 illustrates the location of the Class I PSD areas relative to the Planning Area.

**Table F-3.2 Distance and Direction to Class I Area**

| Class I Area | Distance from Centerpoint (km) | Direction from Centerpoint | Distance to Centroid of Closest Oil and Gas Distribution Zone (km) |
|---|---|---|---|
| Mount Zirkel Wilderness Area | Adjacent | Northwest | 17 |
| Flat Tops Wilderness Area | 100 | Southwest | 77 |
| Rawah Wilderness Area | Inside Planning Area | Northeast | 14 |
| Rocky Mountain National Park | Adjacent | East | 28 |
| Eaglesnest Wilderness Area | Adjacent | Southwest | 37 |

**Figure F-3.1 PSD Class I Areas**



# Project Emissions

An emissions inventory was developed for Alternative B in the DRMP/DEIS, and include oxides of nitrogen ($NO_x$), sulfur dioxide ($SO_2$), carbon monoxide (CO), particulate matter less than or equal to 10 microns in size ($PM_{10}$), particulate matter less than or equal to 2.5 microns in size ($PM_{2.5}$), and volatile organic compounds (VOCs) for oil and gas production activities within the Planning Area. In addition, GHG emissions were calculated, including $CO_2$, $CH_4$, and $N_2O$ for oil and gas and $CH_4$ from enteric fermentation from livestock grazing. Inventories were based upon emission factors from various sources including, but not limited to, manufacturer's data where available, and EPA AP-42, and Gas Research Institute (GRI) emission factors (EPA 1997). (While under contract, Tetra Tech prepared an assumptions document and shared it with the KFO staff to ensure that activity assumptions and parameters used in the emissions calculations were appropriate.)

The emissions inventory developed for Alternative B was used to project impacts for Alternatives A, C and D. The overall development in Alternative B was assumed to be greater than any of the other alternatives, and the impacts for the other alternatives was assumed to be less.

## Alternative A

Alternative A, the No Action Alternative, assesses the continuation of current management, assuming no change from current management direction. Emissions are based upon current oil and gas activity in the Planning Area, the projections of the 1991 Colorado Oil and Gas Leasing and Development RMP Amendment/Environmental Impact Statement (EIS), which analyzed oil and gas development in the Planning Area (BLM 1991b).

The 1991 RMP Amendment analyzed the impacts of 108 wells (40 wildcat wells and 68 development wells). The RMP Amendment assumed 19 acres of disturbed area per well for a total disturbed area of 2,044 acres. A the time of the emissions inventory, there were 109 active wells in the Planning Area, which is one more well than the projected 108 wells (BLM 1991b). Seventy-seven of the 109 wells are located on Federal lands. Most of the 109 wells are located in the McCallum fields. The existing wells have a disturbed acreage of approximately 2 to 3 acres per well, as opposed to the projected 19 acres in the 1991 RMP Amendment. Alternative A assumes 1 well per pad, and a disturbed area of 3 acres per well. This scenario assumes the same well pad configuration as the RFD Scenario (BLM 2008r). Each well pad will include one separator, two water tanks, and four production tanks. Electricity will be driven by a gas-fired generator.

## Alternative B

The RFD Scenario (BLM 2008r) forecasts the amount of drilling activity that could possibly occur in the 20 year period between 2009 and 2028 on Federal, State, and private lands in the Planning Area. The future anticipated drilling activity outlined in the RFD is 370 oil and gas wells (192 wells on Federal lands and 178 wells on fee lands). It is assumed that the 370 wells will be drilled with vertical well bores over a 20 year period, with the expected average life of a well to be 40 years.

Based upon the RFD, it is assumed that there is one well per well pad (BLM 2008r). The average disturbance per well is estimated to be 8 acres, 4 acres for a drill pad, 2 acres for roads, and 2 acres for other infrastructure. The total potential anticipated surface disturbance at the end of the 20 year period is 4,310 acres. This is based upon an existing surface disturbance area of 1,350 acres and 2,960 new acres of disturbed land. The anticipated disturbance area is the gross acreage. The net acreage would be significantly lower due to the reclamation of plugged and abandoned wells. According to the RFD, the existing 1,350 acres of disturbed land (in 2008) accounts for the plugging and reclamation to date (BLM 2008r). The year of peak overall emissions from oil and gas development activities is estimated to be 2028.

## Cumulative Analysis

Far-field cumulative impacts of oil and gas activities will be addressed in a qualitative manner; cumulative sources were not included in the Emissions Inventory. Air Quality results from the DRMP/DEIS are referenced in the cumulative impacts analysis. See Chapter 4, Environmental Consequences.

## Well Location Assumptions

Future potential oil and gas activity in the Planning Area is highly speculative, and little is known about the exact well locations for future development. Due to this uncertainty, modeling analysis to predict potential impacts to air quality was not considered a scientifically defensible analysis.

Assumptions about the type of field production (such as oil or gas) for Alternative B were based upon the RFD Scenario (BLM, 2008r). While well locations are speculative, oil and gas 'Distribution Zones' were created to provide the public and the decision-maker with a visual guide of where current activity exists, and a 'best guess' of where potential future might occur. See Tables F-4.1 and F-4.2. It should be noted, however, that the Alternative B Distribution Zone is just a best guess, without a high degree of certainty. As mentioned above, when adequate data becomes available, such as during the project application and environmental analysis stage, it may become necessary to require air quality modeling to assess the potential impacts resulting from future activities prior to authorization by the BLM.

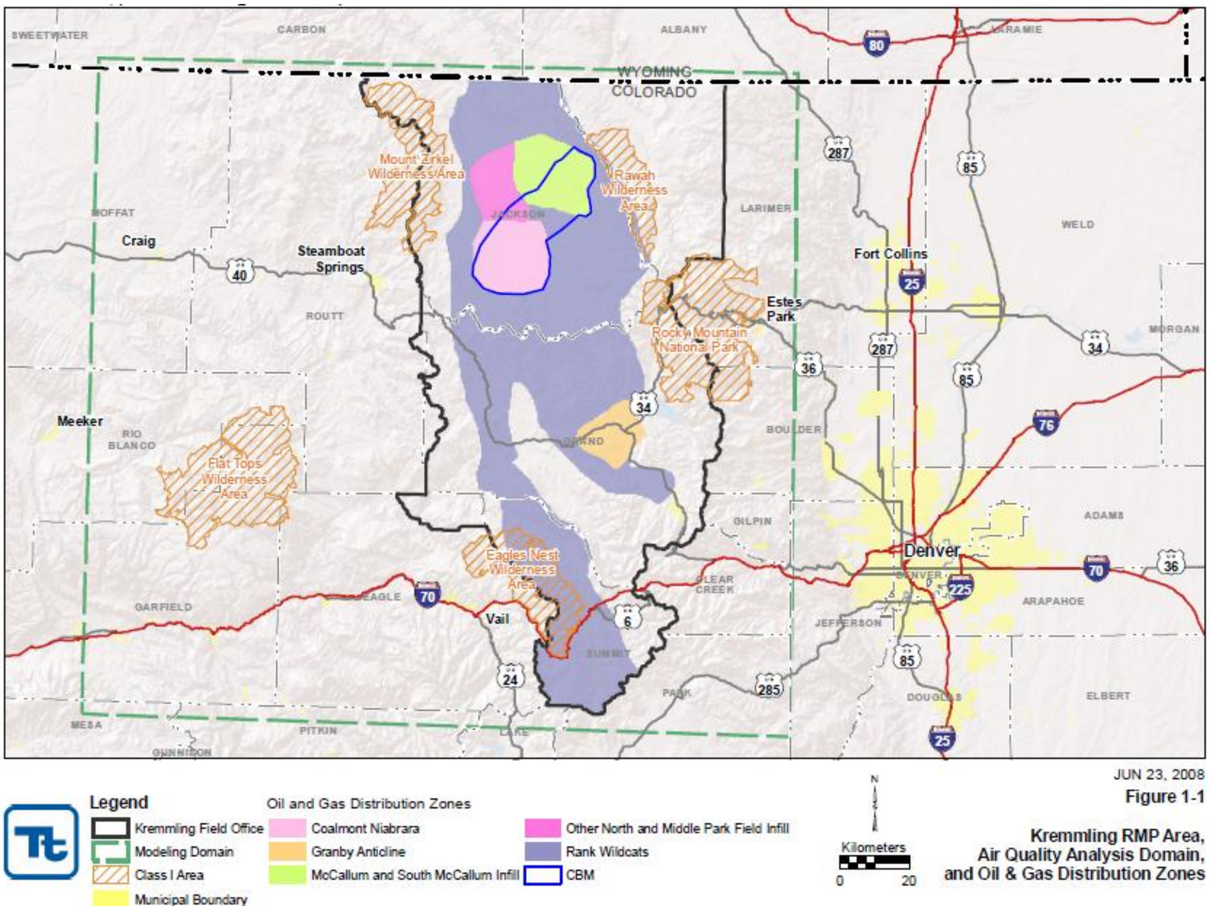
**Table F-4.1 Current Activity (Alternative A) by Distribution Zone**

| Field Name | Current Producing Wells |
|---|---|
| Coalmont Niobrara | 7 |
| CBM | 0 |
| Granby Anticline | 0 |
| McCallum and South McCallum Infill | 84 |
| Other North and Middle Park Field Infill | 1 |
| Rank Wildcats | 17 |
| **Total** | **109** |

**Table F-4.2 Future Anticipated Activity by Distribution Zone (Alternative B)**

| Field Name | Current Producing Wells |
|---|---|
| Coalmont Niobrara | 234 |
| CBM | 40 |
| Granby Anticline | 16 |
| McCallum and South McCallum Infill | 40 |
| Other North and Middle Park Field Infill | 20 |
| Rank Wildcats | 20 |
| **Total** | **370** |

**Figure F-4.1 Distribution Zones for Potential Oil and Gas Development**




# Construction Emissions

Construction emissions for Alternatives A and B included well pad and resource road construction and traffic; rig move and drilling, and associated, traffic; completion and testing, and associated, traffic; and wind erosion during construction activities. Construction emissions for oil and natural gas wells were assumed to be identical.

# Production Emissions

Production emissions included combustion engine emissions and fugitive dust resulting from road travel to, and from, well sites; diesel combustion emissions from haul trucks; combustion emissions from well site heaters; condensate storage tank flashing and flashing control; wind erosion from well pad disturbed areas; and emissions from wellhead engines.

# Emission Calculations

Tables 5.1 through 5.24 provide a detailed analysis of the emission calculations that were performed for this RMP, and include the equations and assumptions that were used to prepare the Emissions Inventory. Tables 5.21 through 5.24 provide per-well totals for 2009, 2011, 2028, and the total emissions by year, respectively.

*Note:* In the following tables, text in red indicates updated information from that in the DRMP/DEIS.

Converting files to the format of this document may have altered the resolution of the tables, therefore, the tables may not be of the highest quality. A PDF copy of the following tables can be found in the online version of the PRMP/FEIS at: http://www.blm.gov/co/st/en/fo/kfo/planning.html

Alternatively, a copy can be requested from the Kremmling Field Office:

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**Table 5.1**

**Emission Source:** **WELL PAD CONSTRUCTION - GENERAL CONSTRUCTION ACTIVITY EMISSIONS**

**Emission Factor From:** AP-42, Section 13.2.3 (EPA 1995)
"Heavy Construction Operations"
AP-42, Section 13.2.2 (EPA 1995)
"Revision to fine fraction rations"

TSP= 1.2 tons/acre/month

**Emission Equation:** Emissions (TPY) = EF (tons/acre/month) x Area (acre) x Equipment Time (hours)

| Area per Well Pad (acre) | Equipment Time per Well Pad (hours) | Emission Control Efficiency | TSP Uncontrolled Emissions per Well Pad (lbs/year) | TSP Controlled Emissions per Well Pad (lbs/year) | $PM_{10}$ Conversion Factor[1] | $PM_{2.5}$ Conversion Factor[1] | Uncontrolled Emissions Per Well Pad (lb/yr) | | Controlled Emissions Per Well Pad (lbs/yr) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | PM10 | PM2.5 | PM10 | PM2.5 |
| 8 | 70 | 80% | 1841.10 | 1472.88 | 0.25 | 0.15 | 460.27 | 69.04 | 368.22 | 55.23 |

Notes:
[1] $PM_{10}$ = 0.25*TSP; $PM_{2.5}$ = 0.15*$PM_{10}$. Conversion factor from AP-42 13.2.2.
Construction activity includes all earthmoving and vehicle operation related to preparation of drill pad.

**Table 5.2**

**Emission Source:** **WELL PAD CONSTRUCTION - VEHICLE ROAD DUST EMISSIONS**

**Emission Factor From:** AP-42, Section 13.2.2 (EPA 2006)
"Unpaved Roads - Industrial Roads"

**Emission Factor Equation:** $E = k \times (s/12)^a \times (W/3)^b$

**Where:**

E = Size-specific emission factor (lb/VMT)
s = Surface material silt content (%)
W = Mean vehicle weight (tons)
k = Empirical constant, particle size multiplier
a = Empirical constant
b = Empirical constant

**Data:**

k = 1.5 for PM10
k = 0.15 for PM2.5
a= 0.9 for PM10 and PM2.5
b= 0.45 for PM10 and PM2.5

| Vehicle | Number of Round Trips per Day | Days on Location | Number of Vehicles | Total Number of Round Trips | Average Vehicle Weight (tons) | Silt Content[1] (%) | Vehicle Miles Travelled per Vehicle (VMT/vehicle) | Control Efficiency | PM10 Emission Factor (lb/VMT) | PM2.5 Emission Factor (lb/VMT) | Uncontrolled PM10 Emissions (lb/pad) | Controlled PM10 Emissions (lb/pad) | Uncontrolled PM2.5 Emissions (lb/pad) | Controlled PM2.5 Emissions (lb/pad) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| low boy hauler | 5 | 2 | 1 | 10 | 40 | 24 | 6 | 80% | 8.98 | 0.90 | 538.76 | 431.00 | 53.88 | 43.10 |
| gravel hauler | 10 | 3 | 3 | 90 | 26 | 24 | 6 | 80% | 7.40 | 0.74 | 3994.34 | 3195.48 | 399.43 | 319.55 |
| water truck (road dust control) | 6 | 3 | 1 | 18 | 26 | 24 | 6 | 80% | 7.40 | 0.74 | 798.87 | 639.10 | 79.89 | 63.91 |
| light duty vehicles (employee access) | 1 | 7 | 2 | 14 | 4.6 | 24 | 6 | 80% | 3.39 | 0.34 | 284.99 | 227.99 | 28.50 | 22.80 |
| | | | | | | | | | | TOTAL | 5616.96 | 4493.57 | 561.70 | 449.36 |

[1]Silt content from AP-42 Table 13.2.2-1 for a freshly graded haul road.

**Table 5.3**

**Emission Source:** **WELL PAD CONSTRUCTION - HEAVY EQUIPMENT EXHAUST EMISSIONS**

**Emission Factor From:** AP-42, Volume II - Mobile Sources (EPA 1985)
"Emissions Factors for Construction Equipment"

**Emission Equation:** Emissions (TPY) = grams pollutant/year / 453.59 grams / 2000 lbs x Load Factor
SO2 Emissions (TPY) = grams SO2/year / 453.59 grams / 2000 lbs x Load Factor x Ultra Low Sulfur Adjustment

| Equipment | Emission Factors[1] (g/hp-hr) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CO | $NO_x$ | $PM_{10}$ | $PM_{2.5}$[2] | $SO_2$ | VOC | $CO_2$[6] | $CH_4$[7] | $N_2O$[7] | Form. | Benzene | Toluene | Xylene |
| Dozer[5] | 2.15 | 7.81 | 0.692 | 0.692 | 0.851 | 0.75 | 521.6 | 0.0252 | 0.0155 | 0.003747 | 0.002962 | 0.001299 | 0.000905 |
| Grader | 2.45 | 7.46 | 0.789 | 0.789 | 0.901 | 0.55 | 521.6 | 0.0252 | 0.0155 | 0.003747 | 0.002962 | 0.001299 | 0.000905 |
| Motor Grader | 2.45 | 7.46 | 0.789 | 0.789 | 0.901 | 0.55 | 521.6 | 0.0252 | 0.0155 | 0.003747 | 0.002962 | 0.001299 | 0.000905 |
| Backhoe | 2.45 | 7.46 | 0.789 | 0.789 | 0.901 | 0.55 | 521.6 | 0.0252 | 0.0155 | 0.003747 | 0.002962 | 0.001299 | 0.000905 |

| Equipment | Engine Horsepower (hp) | Operating Load Factor | Durations (hours)[3] | Polluntant Emissions (lbs/well pad) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CO | $NO_x$ | $PM_{10}$ | $PM_{2.5}$ | $SO_2$[4] | VOC | $CO_2$ | $CH_4$ | $N_2O$ | Form. | Benzene | Toluene | Xylene |
| bulldozer | 300 | 0.4 | 70 | 39.82 | 144.63 | 12.82 | 12.82 | 0.47 | 13.89 | 9660.0 | 0.47 | 0.29 | 0.07 | 0.05 | 0.02 | 0.02 |
| grader | 165 | 0.4 | 70 | 24.95 | 75.98 | 8.04 | 8.04 | 0.28 | 5.60 | 5313.0 | 0.26 | 0.16 | 0.04 | 0.03 | 0.01 | 0.01 |
| motor grader | 165 | 0.4 | 70 | 24.95 | 75.98 | 8.04 | 8.04 | 0.28 | 5.60 | 5313.0 | 0.26 | 0.16 | 0.04 | 0.03 | 0.01 | 0.01 |
| backhoe | 100 | 0.4 | 70 | 15.12 | 46.05 | 4.87 | 4.87 | 0.17 | 3.40 | 3220.0 | 0.16 | 0.10 | 0.02 | 0.02 | 0.01 | 0.01 |
| | | | TOTAL | 104.85 | 342.65 | 33.76 | 33.76 | 1.19 | 28.49 | 23506.0 | 1.13 | 0.70 | 0.17 | 0.13 | 0.06 | 0.04 |

Notes:

[1] AP-42, Volume II - Mobile Sources (EPA 1985) "Emissions Factors for Construction Equipment"

[2] $PM_{2.5}$ emissions assumed equal to PM10 emissions.

[3] Assumes 10 hours per day for 7 days.

[4] Ultra Low Sulfur adjustment based on 15 ppm Ultra Low Sulfur diesel fuel sulfur content compared to 500 ppm (0.05 percent) #2 diesel fuel sulfur content.

[5] Emission factor for track type tractor

[6] From AP-42 Section 3-3 Table 3.3-1 "Emission Factors for Uncontrolled Gasoline and Diesel Industrial Engines"

[7] Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Gas Industry - Table 4-9 (2004) - $N_2O$ emissions of 0.08 g/L of diesel fuel. Diesel density 850 g/L; heating value 19,300 Btu/lb.

**Table 5.4**

**Emission Source:** **WELL PAD CONSTRUCTION - VEHICLE EXHAUST EMISSIONS**

**Emission Equation:** Emissions (TPY) = grams/VMT x VMT / 453.59 grams / 2000 lbs

| | Emission Factors (g/VMT)[1,2,3] | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Equipment | CO | NOx | PM10 | PM2.5[4] | SO2 | VOC | $CO_2$[5] | $CH_4$[6] | $N_2O$[7] | Formaldehyde[8] | Benzene[8] | Toluene[8] | Xylene[8] |
| HD Diesel Engine Trucks (HDDV) | 17.06 | 6.49 | n/a | n/a | 0.32 | 4.82 | 1700 | 0.070 | 0.0432 | 0.0107 | 0.0085 | 0.00371 | 0.0026 |
| LD Diesel Trucks (60 percent)[9] (LDDV) | 2.53 | 1.18 | n/a | n/a | n/a | 0.74 | 230 | 0.018 | 0.0505 | 0.0286 | 0.0148 | 0.00371 | 0.0026 |
| LD Gas Trucks (40 percent) (LDGV) | 9.659 | 0.651 | n/a | n/a | n/a | 0.562 | 330 | 0.119 | 0.0541 | 0.0085 | 0.0151 | 0.00371 | 0.0026 |

| | | | | | | | Pollutant Emissions (lbs/well pad) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Equipment | Class of Vehicle | Days on Location | Number of Vehicles | Number of Round Trips Per Day | Round Trip Distance (mi) | VMT (mi) | CO | NOx | PM10 | PM2.5 | SO2[10] | VOC | CO2 | CH4 | N2O | Formaldehyde | Benzene | Toluene | Xylene |
| low boy hauler | HDDV | 2 | 1 | 5 | 6 | 60 | 2.26 | 0.86 | na | na | 0.001 | 0.64 | 224.87 | 0.0093 | 0.0057 | 0.0014 | 0.0011 | 0.0005 | 0.0003 |
| gravel hauler | HDDV | 3 | 3 | 10 | 6 | 540 | 20.31 | 7.73 | na | na | 0.011 | 5.74 | 2,023.85 | 0.0837 | 0.0515 | 0.0127 | 0.0101 | 0.0044 | 0.0031 |
| water truck (road dust control) - 40 bbls | HDDV | 3 | 1 | 6 | 6 | 108 | 4.06 | 1.55 | na | na | 0.002 | 1.15 | 404.77 | 0.0167 | 0.0103 | 0.0025 | 0.0020 | 0.0009 | 0.0006 |
| light duty vehicles (employee access) - Diesel | LDDV | 7 | 1 | 1 | 6 | 42 | 0.23 | 0.11 | na | na | na | 0.07 | 21.30 | 0.0016 | 0.0047 | 0.0026 | 0.0014 | 0.0003 | 0.0002 |
| light duty vehicles (employee access) - Gas | LDGV | 7 | 1 | 1 | 6 | 42 | 0.89 | 0.06 | na | na | na | 0.05 | 30.56 | 0.0110 | 0.0050 | 0.0008 | 0.0014 | 0.0003 | 0.0002 |
| | | | | | | TOTAL | 27.76 | 10.30 | na | na | 0.015 | 7.64 | 2,705.35 | 0.1224 | 0.0772 | 0.0201 | 0.0160 | 0.0065 | 0.0045 |

Notes:
[1] AP-42, Volume II - Mobile Sources, Appendix H, “Heavy Duty Diesel Trucks” high altitude, “aged” with 50,000 miles service, 2001+ model year (EPA 1995).
[2] AP-42, Volume II - Mobile Sources, Appendix H, “Light Duty Diesel Trucks” high altitude, “aged” with 50,000 miles service, 1990+ model year for NOx, 1984+ model year for CO and HC (EPA 1995).
[3] AP-42, Volume II - Mobile Sources, Appendix H, “Light Duty Gasoline Trucks I” high altitude, “aged” with 50,000 miles service, 1998+ model year (EPA 1995).
[4] PM2.5 emissions assumed equal to PM10 emissions (no PM emission factors avialable from EPA).
[5] Compendium of Greenhouse Gas Emission Methodologies for the Oil and Gas Industry, Table 4-11 (HDDV diesel non-semi truck, LDGT average gasoline car, LDDV large diesel car), CO2 Mobile Source Emission Factors, American Petroleum Institute (2004).
[6] Compendium of Greenhouse Gas Emission Methodologies for the Oil and Gas Industry for CH4, Table 4-9 (HDDV moderate control, LDGT oxidation catalyst, LDDT moderate control), Mobile Source Combustion Emission Factors, Table 4-10 (HDDV Diesel heavy truck, LDGT Gasoline light truck, LDDT Diesel light truck), Default Fuel Economy Factors for Different Types of Mobile Sources, American Petroleum Institute (2004).
[7] Compendium of Greenhouse Gas Emission Methodologies for the Oil and Gas Industry for N2O, Table 4-9 (HDDV moderate control, LDGT oxidation catalyst, LDDT moderate control), Mobile Source Combustion Emission Factors, Table 4-10 (HDDV Diesel heavy truck, LDGT Gasoline light truck, LDDT Diesel light truck), Default Fuel Economy Factors for Different Types of Mobile Sources, American Petroleum Institute (2004).
[8] AP-42, Section 3.3, "Gasoline and Diesel Industrial Engines. Table 3.3-2, "Speciated Organic Compound Emission Factors for Uncontrolled Diesel Engines"
[9] For light duty vehicles (pickup trucks), 60 percent would be diesel-powered, and 40 percent would be gas.
[10] Included in the Pollutant Emissions is the Ultra Low Sulfur adjustment based on 15 ppm Ultra Low Sulfur diesel fuel sulfur content compared to 500 ppm (0.05 percent) #2 diesel fuel sulfur content.(15/500=0.03)

**Table 5.5**

**Emission Source:** **WELL CONSTRUCTION - VEHICLE ROAD DUST EMISSIONS**

**Emission Factor From:** AP-42, Section 13.2.2 (EPA 2006)
"Unpaved Roads" – Industrial roads

**Explanation:**

**Emission Factor Equation:** $E = k \times (s/12)^a \times (W/3)^b$

**Where:**
E = Size-specific emission factor (lb/VMT)
s = Surface material silt content (%)
W = Mean vehicle weight (tons)
k = Empirical constant, particle size multiplier
a = Empirical constant
b = Empirical constant

**Data:**
k = 1.5 for PM10
k = 0.15 for PM2.5
a= 0.9 for PM10 and PM2.5
b= 0.45 for PM10 and PM2.5

| Vehicle | Number of Round Trips per Day | Days on Location | Number of Vehicles | Total Number of Round Trips (per year?) | Mean Vehicle Weight (tons) | Silt Content[1] (%) | Vehicle Miles Travelled per Vehicle (VMT/vehicle) | Control Efficiency | PM10 Emission Factor (lb/VMT) | PM2.5 Emission Factor (lb/VMT) | Uncontrolled PM10 Emissions (lbs/pad) | Uncontrolled PM2.5 Emissions (lbs/pad) | Controlled PM10 Emissions (lbs/pad) | Controlled PM2.5 Emissions (lbs/pad) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel tanker | 1 | 1 | 1 | 1 | 40 | 24 | 6 | 80% | 8.98 | 0.90 | 0.03 | 0.00 | 0.02 | 0.00 |
| Logging truck | 1 | 2 | 1 | 2 | 26 | 24 | 6 | 80% | 7.40 | 0.74 | 0.04 | 0.00 | 0.04 | 0.00 |
| Cementer truck | 1 | 2 | 1 | 2 | 40 | 24 | 6 | 80% | 8.98 | 0.90 | 0.05 | 0.01 | 0.04 | 0.00 |
| Cement supply truck | 1 | 2 | 2 | 4 | 40 | 24 | 6 | 80% | 8.98 | 0.90 | 0.11 | 0.01 | 0.09 | 0.01 |
| Casing crew | 1 | 2 | 1 | 2 | 6 | 24 | 6 | 80% | 3.82 | 0.38 | 0.02 | 0.00 | 0.02 | 0.00 |
| Laydown machine | 1 | 2 | 1 | 2 | 26 | 24 | 6 | 80% | 7.40 | 0.74 | 0.04 | 0.00 | 0.04 | 0.00 |
| Water truck | 2 | 37 | 1 | 74 | 40 | 24 | 6 | 80% | 8.98 | 0.90 | 1.99 | 0.20 | 1.59 | 0.16 |
| Light duty vehicles (trips for bits) | 2 | 5 | 1 | 10 | 6 | 24 | 6 | 80% | 3.82 | 0.38 | 0.11 | 0.01 | 0.09 | 0.01 |
| Light duty vehicles (employee access) | 1 | 37 | 11 | 407 | 4.6 | 24 | 6 | 80% | 3.39 | 0.34 | 4.14 | 0.41 | 3.31 | 0.33 |
| Rig hauler | 5 | 2 | 1 | 10 | 40 | 24 | 6 | 80% | 8.98 | 0.90 | 0.27 | 0.03 | 0.22 | 0.02 |
| TOTAL | | | | | | | | | | | | | 5.46 | 0.55 |

[1]Silt content from AP-42 Table 13.2.2-1 for a freshly graded haul road.

**Table 5.6**

**Emission Source:** **WELL CONSTRUCTION - VEHICLE EXHAUST EMISSIONS**

**Emission Equation:** Emissions (TPY) = grams/VMT x VMT / 453.59 grams / 2000 lbs

| Equipment | CO | NOx | PM10 | PM2.5[4] | SO2 | VOC | CO2[5] | CH4[6] | N2O[7] | Formaldehyde[8] | Benzene[8] | Toluene[8] | Xylene[8] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Emission Factors (g/VMT)[1,2,3] | | | | | | | | | | | | |
| HD Diesel Engine Trucks (HDDV) | 17.06 | 6.49 | n/a | n/a | 0.32 | 4.82 | 1700 | 0.070 | 0.0432 | 0.0107 | 0.0085 | 0.00371 | 0.0026 |
| LD Diesel Trucks (60 percent)[9] (LDDV) | 2.53 | 1.18 | n/a | n/a | n/a | 0.74 | 230 | 0.018 | 0.0505 | 0.0286 | 0.0148 | 0.00371 | 0.0026 |
| LD Gas Trucks (40 percent) (LDGV) | 9.659 | 0.651 | n/a | n/a | n/a | 0.562 | 330 | 0.119 | 0.0541 | 0.0085 | 0.0151 | 0.00371 | 0.0026 |

| Equipment | Class of Vehicle | Days on Location[10] | # of Vehicles | Number of Round Trips Per Day | Round Trip Distance (mi) | VMT (mi) | Pollutant Emissions (lbs/well pad) CO | NOx | PM10 | PM2.5 | SO2[11] | VOC | CO2 | CH4 | N2O | Formaldehyde | Benzene | Toluene | Xylene |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel tanker | HDDV | 5 | 1 | 1 | 6 | 30 | 1.13 | 0.43 | na | na | 0.001 | 0.32 | 112 | 0.0046 | 0.0029 | 0.0007 | 0.0006 | 0.0002 | 0.0002 |
| Logging truck | HDDV | 2 | 1 | 1 | 6 | 12 | 0.45 | 0.17 | na | na | 0.000 | 0.13 | 45 | 0.0019 | 0.0011 | 0.0003 | 0.0002 | 0.0001 | 0.0001 |
| Cementer truck | HDDV | 2 | 1 | 1 | 6 | 12 | 0.45 | 0.17 | na | na | 0.000 | 0.13 | 45 | 0.0019 | 0.0011 | 0.0003 | 0.0002 | 0.0001 | 0.0001 |
| Cement supply truck | HDDV | 2 | 2 | 1 | 6 | 24 | 0.90 | 0.34 | na | na | 0.001 | 0.26 | 90 | 0.0037 | 0.0023 | 0.0006 | 0.0004 | 0.0002 | 0.0001 |
| Casing crew | HDDV | 2 | 1 | 1 | 6 | 12 | 0.45 | 0.17 | na | na | 0.000 | 0.13 | 45 | 0.0019 | 0.0011 | 0.0003 | 0.0002 | 0.0001 | 0.0001 |
| Laydown machine | HDDV | 2 | 1 | 1 | 6 | 12 | 0.45 | 0.17 | na | na | 0.000 | 0.13 | 45 | 0.0019 | 0.0011 | 0.0003 | 0.0002 | 0.0001 | 0.0001 |
| Water truck (100 BBL) | HDDV | 37 | 1 | 2 | 6 | 444 | 16.70 | 6.35 | na | na | 0.009 | 4.72 | 1,664 | 0.0688 | 0.0423 | 0.0105 | 0.0083 | 0.0036 | 0.0025 |
| Light duty vehicles (trips for bits) | LDDV | 5 | 1 | 2 | 6 | 60 | 0.33 | 0.16 | na | na | na | 0.10 | 30 | 0.0023 | 0.0067 | 0.0038 | 0.0020 | 0.0005 | 0.0003 |
| Light duty vehicles (employee access) - Diesel | LDDV | 37 | 8 | 1 | 6 | 1,776 | 9.91 | 4.62 | na | na | na | 2.90 | 901 | 0.0692 | 0.1978 | 0.1118 | 0.0579 | 0.0145 | 0.0102 |
| Light duty vehicles (employee access) - Gas | LDGV | 37 | 3 | 1 | 6 | 666 | 14.18 | 0.96 | na | na | na | 0.83 | 485 | 0.1746 | 0.0794 | 0.0125 | 0.0222 | 0.0054 | 0.0038 |
| Rig hauler | HDDV | 2 | 1 | 5 | 6 | 60 | 2.26 | 0.86 | na | na | 0.04 | 0.64 | 224.87 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| TOTAL (POUNDS) | | | | | | | 47 | 14 | 0 | 0 | 0.05 | 10 | 3,687 | 0.34 | 0.34 | 0.14 | 0.09 | 0.03 | 0.02 |

Notes:

[1] AP-42, Volume II - Mobile Sources, Appendix H, “Heavy Duty Diesel Trucks” high altitude, “aged” with 50,000 miles service, 2001+ model year (EPA 1995).

[2] AP-42, Volume II - Mobile Sources, Appendix H, “Light Duty Diesel Trucks” high altitude, “aged” with 50,000 miles service, 1990+ model year for NOx, 1984+ model year for CO and HC (EPA 1995).

[3] AP-42, Volume II - Mobile Sources, Appendix H, “Light Duty Gasoline Trucks I” high altitude, “aged” with 50,000 miles service, 1998+ model year (EPA 1995).

[4] PM2.5 emissions assumed equal to PM10 emissions

[5] Compendium of Greenhouse Gas Emission Methodologies for the Oil and Gas Industry, Table 4-11 (HDDV diesel non-semi truck, LDGT average gasoline car, LDDV large diesel car), CO2 Mobile Source Emission Factors, American Petroleum Institute (2004).

[6] Compendium of Greenhouse Gas Emission Methodologies for the Oil and Gas Industry for CH4, Table 4-9 (HDDV moderate control, LDGT oxidation catalyst, LDDT moderate control), Mobile Source Combustion Emission Factors, Table 4-10 (HDDV Diesel heavy truck, LDGT Gasoline light truck, LDDT Diesel light truck), Default Fuel Economy Factors for Different Types of Mobile Sources, American Petroleum Institute (2004).

[7] Compendium of Greenhouse Gas Emission Methodologies for the Oil and Gas Industry for N2O, Table 4-9 (HDDV moderate control, LDGT oxidation catalyst, LDDT moderate control), Mobile Source Combustion Emission Factors, Table 4-10 (HDDV Diesel heavy truck, LDGT Gasoline light truck, LDDT Diesel light truck), Default Fuel Economy Factors for Different Types of Mobile Sources, American Petroleum Institute (2004).

[8] AP-42, Section 3.3, "Gasoline and Diesel Industrial Engines. Table 3.3-2, "Speciated Organic Compound Emission Factors for Uncontrolled Diesel Engines"

[9] For light duty vehicles (pickup trucks), 60 percent would be diesel-powered, and 40 percent would be gas.

[10] Well Construction - total of 37 days assumed on location: 2 days for rig move, 2 days to rig up, 30 days drilling, 3 days rig down

[11] Included in the Pollutant Emissions is the Ultra Low Sulfur adjustment based on 15 ppm Ultra Low Sulfur diesel fuel sulfur content compared to 500 ppm (0.05 percent) #2 diesel fuel sulfur content (15 / 500 = 0.03).

**Table 5.7**

**Emission Source:** **WELL CONSTUCTION - DRILLING ENGINES EMISSIONS - Tier 2**

**Emission Equation:** Emissions (lb/well) = EF (g/hp-hr) x Total Horsepower (hp) x LF x Drilling Duration (days/well) x Drilling Duration (hrs/day) / 453.59 g/lb

| Pollutant | Pollutant Emission Factor[1] (g/hp-hr) | Total Horsepower All Engines[2] (hp) | Overall Load Factor | Drilling Activity Duration (days/well) | Drilling Activity Duration (hrs/day) | Emissions (lb/well) | Emissions (lb/hr/well) |
|---|---|---|---|---|---|---|---|
| CO | 2.60 | 4,450 | 0.40 | 30 | 24 | 7,346.19 | 10.20 |
| $NO_x$[3] | 3.80 | 4,450 | 0.40 | 30 | 24 | 10,736.74 | 14.91 |
| $SO_2$[4] | 0.0279 | 4,450 | 0.40 | 30 | 24 | 78.82 | 0.11 |
| VOC | 1.00 | 4,450 | 0.40 | 30 | 24 | 2,825.46 | 3.92 |
| $PM_{10}$ | 0.15 | 4,450 | 0.40 | 30 | 24 | 423.82 | 0.59 |
| $PM_{2.5}$[5] | 0.15 | 4,450 | 0.40 | 30 | 24 | 423.82 | 0.59 |
| $CO_2$[6] | 521.63 | 4,450 | 0.40 | 30 | 24 | 1,473,840.00 | 2,047.00 |
| $CH_4$[7] | 2.52E-02 | 4,450 | 0.40 | 30 | 24 | 71.09 | 0.10 |
| $N_2O$[8] | 1.55E-02 | 4,450 | 0.40 | 30 | 24 | 43.75 | 0.06 |
| Formaldehyde[9] | 3.75E-03 | 4,450 | 0.40 | 30 | 24 | 10.59 | 0.01 |
| Benzene[9] | 2.96E-03 | 4,450 | 0.40 | 30 | 24 | 8.37 | 0.01 |
| Toluene[9] | 1.30E-03 | 4,450 | 0.40 | 30 | 24 | 3.67 | 0.01 |
| Xylene[9] | 9.05E-04 | 4,450 | 0.40 | 30 | 24 | 2.56 | 0.00 |

Notes:

[1]Emission factors for Tier 2 engines taken from "Control of Emissions of Air Pollution From Nonroad Diesel Engines: Final Rule" (63 FR 56970, Oct. 23, 1998) for engines greater than 750 hp and from Diesel Net, Emissions Standards: USA: Nonroad Diesel Engines, Table 1, "EPA Tier 1-3 Nonroad Diesel Engine Emission Standards, g/kWh (g/bhp-hr)." http://www.dieselnet.com/standards/us/nonroad.php

[2]Drilling engine total horsepower is based on two 1,500, two 600, and one 250 hp engine, fueled with ultra low sulfur diesel fuel (15 ppm).

[3]For Tier 2 engines, the combined non-methane hydrocarbon and NOx emission rate is 4.8 g/bhp-hr. Emission calculations presented here assume 3.8 g/bhp-hr for NOx and 1.0 g/bhp-hr for VOC.

[4]AP-42 (EPA 1996), Section 3.3, "Gasoline and Diesel Industrial Engines. Table 3.3-1, "Emission Factors for Uncontrolled Gasoline and Diesel Industrial Engines". Emission rate of 0.00205 lb/hp-hr converts to 0.0279 g/hp-hr when converting units and adjusting for ultra-low sulfur fuel (15 ppm).

[5]$PM_{2.5}$ assumed equivalent to $PM_{10}$ for drilling engines.

[6]AP-42 (EPA 1996), Section 3.3, "Gasoline and Diesel Industrial Engines. Table 3.3-1, "Emission Factors for Uncontrolled Gasoline and Diesel Industrial Engines"; lb/hp-hr = pounds per horsepower-hour. (1.15 lb/hp-hr)

[7]Based on methane emissions of 0.13 g/L of diesel fuel (diesel density of 850 g/L and heating value of 19,300 Btu/lb) from the "Compendium of GHG Emission Methodologies for the Oil and Gas Industry," Table 4-9 (2004).

[8]Based on nitrous oxide emissions of 0.08 g/L of diesel fuel (diesel density of 850 g/L and heating value of 19,300 Btu/lb) from the "Compendium of GHG Emission Methodologies for the Oil and Gas Industry," Table 4-9 (2004).

[9]AP-42 (EPA 1996), Section 3.3, "Gasoline and Diesel Industrial Engines. Table 3.3-2, "Speciated Organic Compound Emission Factors for Uncontrolled Diesel Engines", converted from lb/MMBtu to lb/hp-hr using an average brake-specific fuel consumption (BSFC) of 7,000 Btu/hp-hr.

**Table 5.8**

**Emission Source:** **WELL CONSTUCTION - DRILLING ENGINES EMISSIONS - Tier 4a (2011)**

**Emission Equation:** Emissions (lb/well) = EF (g/hp-hr) x Total Horsepower (hp) x LF x Drilling Duration (days/well) x Drilling Duration (hrs/day) / 453.59 g/lb

| Pollutant | Pollutant Emission Factor[1] (g/hp-hr) | Total Horsepower All Engines[2] (hp) | Overall Load Factor | Drilling Activity Duration (days/well) | Drilling Activity Duration (hrs/day) | Emissions (lb/well) | Emissions (lb/hr/well) |
|---|---|---|---|---|---|---|---|
| CO | 2.60 | 4,450 | 0.40 | 30 | 24 | 7,346.19 | 10.20 |
| $NO_x$ | 2.60 | 4,450 | 0.40 | 30 | 24 | 7,346.19 | 10.20 |
| $SO_2$[3] | 0.0279 | 4,450 | 0.40 | 30 | 24 | 78.82 | 0.11 |
| VOC | 0.30 | 4,450 | 0.40 | 30 | 24 | 847.64 | 1.18 |
| $PM_{10}$ | 0.075 | 4,450 | 0.40 | 30 | 24 | 211.91 | 0.29 |
| $PM_{2.5}$[4] | 0.075 | 4,450 | 0.40 | 30 | 24 | 211.91 | 0.29 |
| $CO_2$[5] | 521.63 | 4,450 | 0.40 | 30 | 24 | 1,473,840.00 | 2,047.00 |
| $CH_4$[6] | 2.52E-02 | 4,450 | 0.40 | 30 | 24 | 71.09 | 0.10 |
| $N_2O$[7] | 1.55E-02 | 4,450 | 0.40 | 30 | 24 | 43.75 | 0.06 |
| Formaldehyde[8] | 3.75E-03 | 4,450 | 0.40 | 30 | 24 | 10.59 | 0.01 |
| Benzene[8] | 2.96E-03 | 4,450 | 0.40 | 30 | 24 | 8.37 | 0.01 |
| Toluene[8] | 1.30E-03 | 4,450 | 0.40 | 30 | 24 | 3.67 | 0.01 |
| Xylene[8] | 9.05E-04 | 4,450 | 0.40 | 30 | 24 | 2.56 | 0.00 |

Notes:

[1]Emission factors for Tier 4 engines taken from "Control of Emissions of Air Pollution From Nonroad Diesel Engines and Fuel" (69 FR 38980, June 29, 2004) for engines used in generator sets greater than 1,200 hp and from Diesel Net, Emissions Standards: USA: Nonroad Diesel Engines, Table 4, "EPA Tier 4 Emission Standards - Engines Above 560 kW, g/kWh (g/bhp-hr)." Available on-line at http://www.dieselnet.com/standards/us/offroad.html.

[2]Drilling engine total horsepower is based on two 1,500, two 600, and one 250 hp engine, fueled with ultra low sulfur diesel fuel (15 ppm).

[3]AP-42 (EPA 1996), Section 3.3, "Gasoline and Diesel Industrial Engines. Table 3.3-1, "Emission Factors for Uncontrolled Gasoline and Diesel Industrial Engines". Emission rate of 0.00205 lb/hp-hr converts to 0.0279 g/hp-hr when converting units and adjusting for ultra-low sulfur fuel (15 ppm).

[4]$PM_{2.5}$ assumed equivalent to $PM_{10}$ for drilling engines.

[5]AP-42 (EPA 1996), Section 3.3, "Gasoline and Diesel Industrial Engines. Table 3.3-1, "Emission Factors for Uncontrolled Gasoline and Diesel Industrial Engines"; lb/hp-hr = pounds per horsepower-hour. (1.15 lb/hp-hr)

[6]Based on methane emissions of 0.13 g/L of diesel fuel (diesel density of 850 g/L and heating value of 19,300 Btu/lb) from the "Compendium of GHG Emission Methodologies for the Oil and Gas Industry," Table 4-9 (2004).

[7]Based on nitrous oxide emissions of 0.08 g/L of diesel fuel (diesel density of 850 g/L and heating value of 19,300 Btu/lb) from the "Compendium of GHG Emission Methodologies for the Oil and Gas Industry," Table 4-9 (2004).

[8]AP-42 (EPA 1996), Section 3.3, "Gasoline and Diesel Industrial Engines. Table 3.3-2, "Speciated Organic Compound Emission Factors for Uncontrolled Diesel Engines", converted from lb/MMBtu to lb/hp-hr using an average brake-specific fuel consumption (BSFC) of 7,000 Btu/hp-hr.

**Table 5.9**

**Emission Source:** **WELL CONSTRUCTION - DRILLING ENGINES EMISSIONS - Tier 4b (2015)**

**Emission Equation:** Emissions (lb/well) = EF (g/hp-hr) x Total Horsepower (hp) x LF x Drilling Duration (days/well) x Drilling Duration (hrs/day) / 453.59 g/l

| Pollutant | Pollutant Emission Factor[1] (g/hp-hr) | Total Horsepower All Engines[2] (hp) | Overall Load Factor | Drilling Activity Duration (days/well) | Drilling Activity Duration (hrs/day) | Emissions (lb/well) | Emissions (lb/hr/well) |
|---|---|---|---|---|---|---|---|
| CO | 2.60 | 4,450 | 0.40 | 30 | 24 | 7,346.19 | 10.20 |
| $NO_x$ | 2.60 | 4,450 | 0.40 | 30 | 24 | 7,346.19 | 10.20 |
| $SO_2$[3] | 0.0279 | 4,450 | 0.40 | 30 | 24 | 78.82 | 0.11 |
| VOC | 0.14 | 4,450 | 0.40 | 30 | 24 | 395.56 | 0.55 |
| $PM_{10}$ | 0.022 | 4,450 | 0.40 | 30 | 24 | 62.16 | 0.09 |
| $PM_{2.5}$[4] | 0.022 | 4,450 | 0.40 | 30 | 24 | 62.16 | 0.09 |
| $CO_2$[5] | 521.63 | 4,450 | 0.40 | 30 | 24 | 1,473,840.00 | 2,047.00 |
| $CH_4$[6] | 2.52E-02 | 4,450 | 0.40 | 30 | 24 | 71.09 | 0.10 |
| $N_2O$[7] | 1.55E-02 | 4,450 | 0.40 | 30 | 24 | 43.75 | 0.06 |
| Formaldehyde[8] | 3.75E-03 | 4,450 | 0.40 | 30 | 24 | 10.59 | 0.01 |
| Benzene[8] | 2.96E-03 | 4,450 | 0.40 | 30 | 24 | 8.37 | 0.01 |
| Toluene[8] | 1.30E-03 | 4,450 | 0.40 | 30 | 24 | 3.67 | 0.01 |
| Xylene[8] | 9.05E-04 | 4,450 | 0.40 | 30 | 24 | 2.56 | 0.00 |

Notes:

[1]Emission factors for Tier 4 engines taken from "Control of Emissions of Air Pollution From Nonroad Diesel Engines and Fuel: Final Rule" (69 FR 38980, June 29, 2004) for engines used in generator sets greater than 1,200 hp and from Diesel Net, Emissions Standards: USA: Nonroad Diesel Engines, Table 4, "EPA Tier 4 Emission Standards - Engines Above 560 kW, g/kWh (g/bhp-hr)." Available on-line at http://www.dieselnet.com/standards/us/offroad.html.

[2]Drilling engine total horsepower is based on two 1,500, two 600, and one 250 hp engine, fueled with ultra low sulfur diesel fuel (15 ppm).

[3]AP-42 (EPA 1996), Section 3.3, "Gasoline and Diesel Industrial Engines. Table 3.3-1, "Emission Factors for Uncontrolled Gasoline and Diesel Industrial Engines". Emission rate of 0.00205 lb/hp-hr converts to 0.0279 g/hp-hr when converting units and adjusting for ultra-low sulfur fuel (15 ppm).

[4]$PM_{2.5}$ assumed equivalent to $PM_{10}$ for drilling engines.

[5]AP-42 (EPA 1996), Section 3.3, "Gasoline and Diesel Industrial Engines. Table 3.3-1, "Emission Factors for Uncontrolled Gasoline and Diesel Industrial Engines"; lb/hp-hr = pounds per horsepower-hour. (1.15 lb/hp-hr)

[6]Based on methane emissions of 0.13 g/L of diesel fuel (diesel density of 850 g/L and heating value of 19,300 Btu/lb) from the "Compendium of GHG Emission Methodologies for the Oil and Gas Industry," Table 4-9 (2004).

[7]Based on nitrous oxide emissions of 0.08 g/L of diesel fuel (diesel density of 850 g/L and heating value of 19,300 Btu/lb) from the "Compendium of GHG Emission Methodologies for the Oil and Gas Industry," Table 4-9 (2004).

[8]AP-42 (EPA 1996), Section 3.3, "Gasoline and Diesel Industrial Engines. Table 3.3-2, "Speciated Organic Compound Emission Factors for Uncontrolled Diesel Engines", converted from lb/MMBtu to lb/hp-hr using an average brake-specific fuel consumption (BSFC) of 7,000 Btu/hp-hr.

**Table 5.10**

**Emission Source:** **WELL COMPLETION AND TESTING - FLARING EMISSIONS**

**Emission Factor From:** AP-42, Section 1.4 (EPA 1998)
"Natural Gas Combustion"

**Emission Equations:** Emissions (TPY) = Average gas emitted (MMscf) x EF (lb/MMscf) / 2000 lbs

**Data:** Average gas emitted (per well) = 0.4 MMscf
100% flared, 0% vented

| Pollutant | lb/MMscf[2] | Emissions (lb/well) | Duration[2] (hours) | Hourly Emissions per Well (lb/hr/well) |
|---|---|---|---|---|
| CO | 84 | 33.6 | 48 | 0.70 |
| NOx | 100 | 40 | 48 | 0.83 |
| PM10 | 7.6 | 3.04 | 48 | 0.06 |
| PM2.5[1] | 7.6 | 3.04 | 48 | 0.06 |
| SO2 | 0.6 | 0.24 | 48 | 0.01 |
| VOC | 5.5 | 2.2 | 48 | 0.05 |
| $CO_2$ | 120,000 | 48000 | 48 | 1000.00 |
| $CH_4$ | 2.3 | 0.92 | 48 | 0.02 |
| $N_2O$ | 2.2 | 0.88 | 48 | 0.02 |
| Benzene | 2.10E-03 | 8.40E-04 | 48 | 1.75E-05 |
| Toluene | 3.40E-03 | 1.36E-03 | 48 | 2.83E-05 |
| Hexane | 1.81E+00 | 7.23E-01 | 48 | 1.51E-02 |

Notes:
[1] $PM_{2.5}$ emissions assumed equal to PM10 emissions
[2] Assumes there are two days of flaring before going to sales

**Natural Gas Analysis**

| Gas Component | | Volumetric Concentration mol% | Molecular Weight (lb/lb-mol) | Gas Weight (lb/lb/mol) | Weight Percent wt % | Weight [2] (lb/MMscf) |
|---|---|---|---|---|---|---|
| Carbon Dioxide | C0 2: | 1.49 | 43.99 | 0.65 | 1.63 | 691.35 |
| Nitrogen | N 2: | 0.58 | 28.02 | 0.16 | 0.40 | 171.02 |
| Hydrogen Sulfide | H 2s: | 0.00 | 34.06 | 0.00 | 0.00 | 0.00 |
| Methane | C1: | 67.48 | 16.04 | 10.82 | 26.93 | 11,435.41 |
| Ethane | C2: | 13.68 | 30.07 | 4.11 | 10.23 | 4,344.78 |
| **Non-Reactive, non-HAP** | | **83.23** | **152.18** | **15.75** | **39.20** | **16,642.57** |
| Propane | C3: | 10.88 | 44.10 | 4.80 | 11.94 | 5,071.19 |
| Iso-Butane | IC4: | 1.07 | 58.12 | 0.62 | 1.55 | 659.50 |
| Nor-Butane | NC4: | 2.94 | 58.12 | 1.71 | 4.26 | 1,807.91 |
| Iso-Pentane | IC5: | 0.54 | 72.15 | 0.39 | 0.97 | 412.79 |
| Nor-Pentane | NC5: | 0.62 | 72.15 | 0.45 | 1.12 | 473.57 |
| Hexane Plus | C6+: | 0.71 | 100.21 | 0.71 | 1.77 | 749.89 |
| **Reactive VOC** | | **16.77** | **404.85** | **8.68** | **21.61** | **9,174.86** |
| **Totals** | | **100.00** | **--** | **40.19** | **100.00** | **42,460.00** |

[1] Gas analysis from Jackson County, CO 11/21/07
[2] Gas density is 0.04246 lb/scf (19.26 g/scf) - Need to determine gas density for sample being used

**Table 5.11**

**Emission Source:** **WASTE POND EVAPORATION**

**Emission Factor From:** CDPHE-APCD - based on tests conducted by Williams E&P

**Emission Factor Equatio** Emissions (TPY) = lbs VOC/bbl x bbl water to waste pit / 2000 lbs

| Barrels | Emission Factor[1] (lbs VOC/bbl) | Emissions (lb/well) |
|---|---|---|
| 10,000 | 0.07 | 700 |

[1] Based on test conducted by Williams E&P for CDPHE-APCD
(Need to find a better emission factor)

**Table 5.12**

**Emission Source:** **WELL COMPLETION AND TESTING - VEHICLE ROAD DUST EMISSIONS**

**Emission Factor From:** AP-42, Section 13.2.2 (EPA 2006)
"Unpaved Roads" – Industrial roads

**Emission Factor Equation:** $E = k \times (s/12)^a \times (W/3)^b$

**Where:**
E = Size-specific emission factor (lb/VMT)
s = Surface material silt content (%)
W = Mean vehicle weight (tons)
k = Empirical constant, particle size multiplier
a = Empirical constant
b = Empirical constant

**Data:**
k = 1.5 for PM10
k = 0.15 for PM2.5
a= 0.9 for PM10 and PM2.5
b= 0.45 for PM10 and PM2.5

| Vehicle | Number of Round Trips per Day | Days on Location | Number of Vehicles | Total Number of Round Trips (per year?) | Mean Vehicle Weight (tons) | Silt Content[1] (%) | Vehicle Miles Travelled per Vehicle (VMT/vehicle) | Control Efficiency | PM10 Emission Factor (lb/VMT) | PM2.5 Emission Factor (lb/VMT) | Uncontrolled PM10 Emissions (lbs/pad) | Uncontrolled PM2.5 Emissions (lbs/pad) | Controlled PM10 Emissions (lbs/pad) | Controlled PM2.5 Emissions (lbs/pad) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Casing hauler | 6 | 4 | 1 | 24 | 40 | 24 | 6 | 80% | 8.98 | 0.90 | 1293 | 129 | 1034 | 103 |
| Completion rig | 1 | 1 | 1 | 1 | 61.5 | 24 | 6 | 80% | 10.90 | 1.09 | 65 | 7 | 52 | 5 |
| Logging truck | 2 | 2 | 1 | 4 | 26 | 24 | 6 | 80% | 7.40 | 0.74 | 178 | 18 | 142 | 14 |
| Sand truck | 3 | 5 | 1 | 15 | 40 | 24 | 6 | 80% | 8.98 | 0.90 | 808 | 81 | 647 | 65 |
| Frac pumper | 1 | 2 | 13 | 26 | 40 | 24 | 6 | 80% | 8.98 | 0.90 | 1401 | 140 | 1121 | 112 |
| Fracmaster delivery | 1 | 2 | 2 | 4 | 40 | 24 | 6 | 80% | 8.98 | 0.90 | 216 | 22 | 172 | 17 |
| Water truck (road dust control) | 3 | 5 | 1 | 15 | 40 | 24 | 6 | 80% | 8.98 | 0.90 | 808 | 81 | 647 | 65 |
| Light duty vehicles (employee access) | 2 | 10 | 6 | 120 | 4.6 | 24 | 6 | 80% | 3.39 | 0.34 | 2443 | 244 | 1954 | 195 |
| Water truck - frac water | 12 | 8 | 2 | 192 | 40 | 24 | 6 | 80% | 8.98 | 0.90 | 10344 | 1034 | 8275 | 828 |
| TOTAL | | | | | | | | | | | | | 14044 | 1404 |

[1]Silt content from AP-42 Table 13.2.2-1 for a freshly graded haul road.

**Table 5.13**

**Emission Source:** **WELL COMPLETION AND TESTING - VEHICLE EXHAUST EMISSIONS**

**Emission Equation:** Emissions (TPY) = grams/VMT x VMT / 453.59 grams / 2000 lbs

| | Emission Factors (g/VMT)[1,2,3] | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Equipment | CO | NOx | PM10 | PM2.5[4] | $SO_2$ | VOC | $CO_2$[5] | $CH_4$[6] | $N_2O$[7] | Formaldehyde[8] | Benzene[8] | Toluene[8] | Xylene[8] |
| HD Diesel Engine Trucks (HDDV) | 17.06 | 6.49 | n/a | n/a | 0.32 | 4.82 | 1700 | 0.07028112 | 0.0432 | 0.0107 | 0.0085 | 0.00371 | 0.0026 |
| LD Diesel Trucks (60 percent)[9] (LDDV) | 2.53 | 1.18 | n/a | n/a | n/a | 0.74 | 230 | 0.01768291 | 0.0505 | 0.0286 | 0.0148 | 0.00371 | 0.0026 |
| LD Gas Trucks (40 percent) (LDGV) | 9.659 | 0.651 | n/a | n/a | n/a | 0.562 | 330 | 0.11893728 | 0.0541 | 0.0085 | 0.0151 | 0.00371 | 0.0026 |

| | | | | | | | Pollutant Emissions (lbs/well pad) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Equipment | Class of Vehicle | Days on Location[10] | # of Vehicles | Number of Round Trips Per Day | Round Trip Distance (mi) | VMT (mi) | CO | NOx | PM10 | PM2.5 | $SO_2$[11] | VOC | $CO_2$ | $CH_4$ | $N_2O$ | Formaldehyde | Benzene | Toluene | Xylene |
| Casing hauler | HDDV | 4 | 1 | 6 | 6 | 144 | 5 | 2 | na | na | 0.003 | 2 | 540 | 0.022 | 0.014 | 0.003 | 0.003 | 0.001 | 0.001 |
| Completion rig | HDDV | 1 | 1 | 1 | 6 | 6 | 0 | 0 | na | na | 0.000 | 0 | 22 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 |
| Logging truck | HDDV | 2 | 1 | 2 | 6 | 24 | 1 | 0 | na | na | 0.001 | 0 | 90 | 0.004 | 0.002 | 0.001 | 0.000 | 0.000 | 0.000 |
| Sand truck | HDDV | 5 | 1 | 3 | 6 | 90 | 3 | 1 | na | na | 0.002 | 1 | 337 | 0.014 | 0.009 | 0.002 | 0.002 | 0.001 | 0.001 |
| Frac pumper | HDDV | 2 | 13 | 1 | 6 | 156 | 6 | 2 | na | na | 0.003 | 2 | 585 | 0.024 | 0.015 | 0.004 | 0.003 | 0.001 | 0.001 |
| Fracmaster delivery | HDDV | 2 | 2 | 1 | 6 | 24 | 1 | 0 | na | na | 0.001 | 0 | 90 | 0.004 | 0.002 | 0.001 | 0.000 | 0.000 | 0.000 |
| Water truck (road dust control) | HDDV | 5 | 1 | 3 | 6 | 90 | 3 | 1 | na | na | 0.002 | 1 | 337 | 0.014 | 0.009 | 0.002 | 0.002 | 0.001 | 0.001 |
| Light duty vehicles (employee access) - Diesel | LDDV | 10 | 4 | 2 | 6 | 480 | 3 | 1 | na | na | na | 1 | 243 | 0.019 | 0.053 | 0.030 | 0.016 | 0.004 | 0.003 |
| Light duty vehicles (employee access) - Gas | LDGV | 10 | 2 | 2 | 6 | 240 | 5 | 0 | na | na | na | 0 | 175 | 0.063 | 0.029 | 0.004 | 0.008 | 0.002 | 0.001 |
| Water truck - frac water 130 BBL | HDDV | 8 | 2 | 12 | 6 | 1,152 | 43 | 16 | na | na | 0.024 | 12 | 4,318 | 0.178 | 0.110 | 0.027 | 0.022 | 0.009 | 0.007 |
| TOTAL (POUNDS) | | | | | | | 71 | 26 | 0 | 0 | 0.04 | 19 | 6,737 | 0.34 | 0.24 | 0.07 | 0.06 | 0.02 | 0.01 |

Notes:

[1] AP-42, Volume II - Mobile Sources, Appendix H, "Heavy Duty Diesel Trucks" high altitude, "aged" with 50,000 miles service, 2001+ model year (EPA 1995).

[2] AP-42, Volume II - Mobile Sources, Appendix H, "Light Duty Diesel Trucks" high altitude, "aged" with 50,000 miles service, 1990+ model year for NOx, 1984+ model year for CO and HC (EPA 1995).

[3] AP-42, Volume II - Mobile Sources, Appendix H, "Light Duty Gasoline Trucks I" high altitude, "aged" with 50,000 miles service, 1998+ model year (EPA 1995).

[4] PM2.5 emissions assumed equal to PM10 emissions (no PM emission factors avialable from EPA).

[5] Compendium of Greenhouse Gas Emission Methodologies for the Oil and Gas Industry, Table 4-11 (HDDV diesel non-semi truck, LDGT average gasoline car, LDDV large diesel car), $CO_2$ Mobile Source Emission Factors, American Petroleum Institute (2004).

[6] Compendium of Greenhouse Gas Emission Methodologies for the Oil and Gas Industry for $CH_4$, Table 4-9 (HDDV moderate control, LDGT oxidation catalyst, LDDT moderate control), Mobile Source Combustion Emission Factors, Table 4-10 (HDDV Diesel heavy truck, LDGT Gasoline light truck, LDDT Diesel light truck), Default Fuel Economy Factors for Different Types of Mobile Sources, American Petroleum Institute (2004).

[7] Compendium of Greenhouse Gas Emission Methodologies for the Oil and Gas Industry for $N_2O$, Table 4-9 (HDDV moderate control, LDGT oxidation catalyst, LDDT moderate control), Mobile Source Combustion Emission Factors, Table 4-10 (HDDV Diesel heavy truck, LDGT Gasoline light truck, LDDT Diesel light truck), Default Fuel Economy Factors for Different Types of Mobile Sources, American Petroleum Institute (2004).

[8] AP-42, Section 3.3, "Gasoline and Diesel Industrial Engines. Table 3.3-2, "Speciated Organic Compound Emission Factors for Uncontrolled Diesel Engines"

[9] For light duty vehicles (pickup trucks), 60 percent would be diesel-powered, and 40 percent would be gas.

[10] Well Completion and Testing - total of 10 days assumed on location: 8 days completion, 2 days testing.

[11] Included in the Pollutant Emissions is the Ultra Low Sulfur adjustment based on 15 ppm Ultra Low Sulfur diesel fuel sulfur content compared to 500 ppm (0.05 percent) #2 diesel fuel sulfur content (15 / 500 = 0.03).

**Table 5.14**

**Emission Source:** **COMPLETION - FRAC PUMP ENGINES**

**Emission Factor From:** AP-42, Section 3.3 (EPA 1996)
"Gasoline and Diesel Industrial Engines"

**Emission Equation:** Emissions (lb/well) = grams/hp-hr x hrs of use x Load Factor x hp / 453.59 grams

**Data:**

| | | |
|---|---|---|
| Engine Horsepower: | **2200** | hp |
| Operating Load Factor: | **0.6** | |
| Duration (hours)[2]: | **84** | hours |

| **Pollutant** | **Emission Factors g/hp-hr** | **Emissions (lbs/well pad)** |
|---|---|---|
| CO | 3.03E+00 | 740.68 |
| NOx | 14.06129 | 3437.28 |
| $PM_{10}$ | 9.98E-01 | 243.94 |
| $PM_{2.5}$[1] | 9.98E-01 | 243.94 |
| $SO_2$ | 9.30E-01 | 227.30 |
| VOC | 1.14E+00 | 278.76 |
| CO2 | 521.63 | 127512.00 |
| $CH_4$[3] | 1.16E-01 | 28.31 |
| Form. | 3.75E-03 | 0.92 |
| Benzene | 2.96E-03 | 0.72 |
| Toluene | 1.30E-03 | 0.32 |
| Xylene | 9.05E-04 | 0.22 |

Notes:
[1] $PM_{2.5}$ emissions assumed equal to $PM_{10}$ emissions.
[2] Assumes 12 hours per day for 14 days.
[3] Compendium of Greenhouse Gas Emission Methodologies for the Oil and Gas Industry Table 4-5 (assumes TOC contains 10 wt% CH4 in exhaust).

**Table 5.15**

**Emission Source:** **PRODUCTION - HEATER/TREATER EMISSIONS**

**Emission Factor From:** AP-42, Section 1.4 (EPA 1998) "Natural Gas Combustion"

**Emission Equation:** Emissions (TPY) = Emission Factor (lbs/MMscf) x Fuel Heating Value (Btu/scf) x Heat Rate (MMBtu/hr) x Hours of Operation (hrs/yr) / 2000 lbs

**Data:**

| | | |
|---|---|---|
| Fuel Heating Value = | 1020 | Btu/scf |
| Heat Rate = | 0.5 | MMBtu/hr |
| Hours of Operation = | 8760 | hrs/yr |

**Assumptions:** 500K BTU/hr heater/treater; Operates year round

| Pollutant | Emission Factor[1] (lb/MMscf) | Emissions (lb/hr) | Emissions (lb/well pad) |
|---|---|---|---|
| CO | 84 | 0.04 | 360.71 |
| NOx | 100 | 0.05 | 429.41 |
| PM10 | 7.6 | 0.00 | 32.64 |
| PM2.5 | 7.6 | 3.73E-03 | 32.64 |
| SO2 | 0.6 | 0.00 | 2.58 |
| VOC | 5.5 | 2.70E-03 | 23.62 |
| CO2 | 120000 | 58.82 | 515,294.12 |
| CH4 | 2.3 | 0.00 | 9.88 |
| N2O | 2.2 | 0.00 | 9.45 |
| Formaldehyde | 0.075 | 0.00 | 0.32 |
| Benzene | 0.0021 | 0.00 | 0.01 |
| Ethylbenzene | NA | NA | NA |
| Toluene | 0.0034 | 0.00 | 0.01 |
| Xylene | NA | NA | NA |

**Table 5.16**

**Emission Source:** **PRODUCTION - WELL PAD TANKS**

**Emission Factor From:** APCD's PS Memo 05-01 document, Section 4.1 for remainder of Colorado

**Assumptions:** 4 - 400 bbl Condensate Tanks
2 - 400 bbl Produced Water Tanks[1]

| | | | |
|---|---|---|---|
| | Condensate Throughput: | 150 | bbl/day/pad |
| **Data:** | Condensate Throughput: | 4500 | bbl/month/pad |
| | Condensate Throughput: | 54000 | bbl/year/pad |
| | Control efficiency[2] (%): | 95% | |

| Pollutant | Emission Factor (lbs/bbl) | Uncontrolled Emissions (lb/pad) | Controlled Emissions[2] (lb/pad) | Emissions (lb/hr) | Uncontrolled Emissions (tons/yr) | Controlled Emissions (tons/yr) |
|---|---|---|---|---|---|---|
| VOC | 11.8 | 637,200.00 | 31,860.00 | 72.74 | 318.60 | 15.93 |
| Benzene | 0.034 | 1,836.00 | 91.80 | 0.21 | 0.92 | 0.92 |
| n-Hexane | 0.185 | 9,990.00 | 499.50 | 1.14 | 5.00 | 5.00 |

Notes:
[1] Produced water tanks are assumed to have minimal emissions and they are not quantified.
[2]Assumed to have 95% control based on (CPDHE 2007) Regulation 7 "Emissions of Volatile Organic Compounds (5 CCR 1001-9)"
Effective Statewide May 1, 2008 (CPDHE 2007 Reg 7, Sec XVII)
95 percent on Condensate Tank (with uncontrolled VOC emissions >20 TPY)

**Table 5.17**

**Emission Source:** **PRODUCTION - GAS GENERATOR**[1]

**Emission Factor From:** AP-42, Section 3.2 (EPA 2000)
"Natural Gas-fired Reciprocating Engines"

**Assumptions:**

| | | |
|---|---|---|
| Gas Generator Power: | 25 | kW |
| Horsepower: | 33.5 | hp |
| Heat Rate: | 0.0853 | MMBtu/hr |

**Emission Equation:** Emissions (lb/hr) = EF (lbs/MMBtu) x MMBtu/hr x 8760 hrs / 2000 lbs

| Pollutant | Emission Factor (lb/MMBtu) | Emissions (lb/hr) | Emissions (lb/yr) | Emissions (tons/yr) | Emissions (lb/well) |
|---|---|---|---|---|---|
| CO | 3.17E-01 | 2.70E-02 | 236.87 | 0.12 | 236.87 |
| $NO_x$ | 4.08 | 3.48E-01 | 3,048.69 | 1.52 | 3,048.69 |
| $SO_2$ | 5.88E-04 | 5.02E-05 | 0.44 | 0.00 | 0.44 |
| $PM_{10}$ | 7.71E-05 | 6.58E-06 | 0.06 | 0.00 | 0.06 |
| $PM_{2.5}$ | 7.71E-05 | 6.58E-06 | 0.06 | 0.00 | 0.06 |
| $CO_2$ | 1.10E+02 | 9.38E+00 | 82,195.08 | 41.10 | 82,195.08 |
| Benzene | 4.40E-04 | 3.75E-05 | 0.33 | 0.00 | 0.33 |
| Ethylbenzene | 3.97E-05 | 3.39E-06 | 0.03 | 0.00 | 0.03 |
| Form. | 5.52E-02 | 4.71E-03 | 41.25 | 0.02 | 41.25 |
| Hexane | 4.45E-04 | 3.80E-05 | 0.33 | 0.00 | 0.33 |
| Toluene | 4.08E-04 | 3.48E-05 | 0.30 | 0.00 | 0.30 |
| Xylene | 1.84E-04 | 1.57E-05 | 0.14 | 0.00 | 0.14 |

[1] Well head engine electric driven by natural gas fired generator until power lines run to locations

**Table 5.18**

| | | | |
|---|---|---|---|
| **Emission Source:** | **PRODUCTION - WIND EROSION** | | |
| **Emission Factor From:** | EPA-450/3-98-008 (EPA 1998) | | |
| | "Control of Fugitive Dust Sources" | | |
| **Emission Equation:** | TSP (lb/acre/month) = 1.7 x (s/1.5) x ([365-p]/235) x (f/15) | | |
| | Emissions (TPY) = TSP x disturbed acreage x 12 months / 2000 lbs | | |
| **Where:** | s = | silt content (percent) | |
| | p = | number of days with >.001 in precipitation (not used) | |
| | f = | percent of time wind speed >5.4 (m/s) [equivalent to 12 mph] | |
| **Data:** | s = | 20 | percent silt (average) |
| | f = | 36.6 | percent of time wind speed >5.4 (m/s) [equivalent to 12 mph] |
| | | | from Rock Springs FAA Airport (Wyoming)1985, 1987-1990 |
| | Disturbed acreage= | 8 | acres |
| | **TSP =** | **85.9** | **(lb/acre/month)** |
| **Assume Control Efficiency:** | | 80% | for watering |
| **Assumptions per pad/road:** | | 8 acres per well pad (assumes 4 acre drill pad, 2 acre road, 2 acre other infrastructure) | |

| Particulate | Conversion Factor[1] | Uncontrolled Emissions (lb/month) | Uncontrolled Emissions (lb/year) | Controlled Emissions[2] (lbs/pad/year) |
|---|---|---|---|---|
| TSP | na | 687.21 | 8,247 | 6,597.26 |
| $PM_{10}$ | 0.25 | 171.80 | 2,062 | 1,649.32 |
| $PM_{2.5}$ | 0.15 | 103.08 | 1,237 | 989.59 |

Notes:

[1] $PM_{10}$ = 0.25*TSP; $PM_{2.5}$ = 0.15*$PM_{10}$ This conversion factor came from AP-42 13.2.2 background document "Background Document for Revision to Fine Fraction Ratios Used for AP-42 Fugitive Dust Emission Factors" (2006).

[2] Assumes 50% control by watering

| | | |
|---|---|---|
| 1985 | 37.82 | |
| 1986 | 27.95 | |
| 1987 | 38.88 | 36.608 |
| 1988 | 39.46 | |
| 1989 | 38.93 | |

**Table 5.19**

**Emission Source:** **WELL PRODUCTION - VEHICLE ROAD DUST EMISSIONS**

**Emission Factor From:** AP-42, Section 13.2.2 (EPA 2006)
"Unpaved Roads" – Industrial roads

**Emission Factor Equation:** $E = k \times (s/12)^a \times (W/3)^b$

**Where:**
E = Size-specific emission factor (lb/VMT)
s = Surface material silt content (%)
W = Mean vehicle weight (tons)
k = Empirical constant, particle size multiplier
a = Empirical constant
b = Empirical constant

**Data:**
k = 1.5 for PM10
k = 0.15 for PM2.5
a= 0.9 for PM10 and PM2.5
b= 0.45 for PM10 and PM2.5

| Vehicle | Number of Round Trips per Week | Number of Vehicles | Total Number of Round Trips | Mean Vehicle Weight (tons) | Silt Content[1] (%) | Vehicle Miles Travelled per Vehicle (VMT/vehicle) | Control Efficiency | PM10 Emission Factor (lb/VMT) | PM2.5 Emission Factor (lb/VMT) | Uncontrolled PM10 Emissions (lbs/pad) | Uncontrolled PM2.5 Emissions (lbs/pad) | Controlled PM10 Emissions (lbs/pad) | Controlled PM2.5 Emissions (lbs/pad) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Water truck | 2 | 1 | 104 | 40 | 8.4 | 6 | 80% | 3.49 | 0.35 | 2178 | 218 | 1743 | 174 |
| Condensate truck | 3 | 1 | 156 | 40 | 8.4 | 6 | 80% | 3.49 | 0.35 | 3267 | 327 | 2614 | 261 |
| Light duty vehicles (employee access) | 7 | 1 | 364 | 46 | 8.4 | 6 | 80% | 3.72 | 0.37 | 8118 | 812 | 6495 | 649 |
| TOTAL | | | | | | | | | | 13564 | 1356 | 10851 | 1085 |

[1]Silt content from AP-42 Table 13.2.2-1 for a haul road. (replaced freshly graded, used for construction, but not production!!!)

**Table 5.20**

**Emission Source:** **WELL PRODUCTION - VEHICLE EXHAUST EMISSIONS**

**Emission Equation:** Emissions (TPY) = grams/VMT x VMT / 453.59 grams / 2000 lbs

| | Emission Factors (g/VMT)[1,2,3] | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Equipment | CO | NOx | PM10 | PM2.5[4] | SO2 | VOC | CO2[5] | CH4[6] | N2O[7] | Formaldehyde[8] | Benzene[8] | Toluene[8] | Xylene[8] |
| HD Diesel Engine Trucks (HDDV) | 17.06 | 6.49 | n/a | n/a | 0.32 | 4.82 | 1700 | 0.070 | 0.0432 | 0.0107 | 0.0085 | 0.00371 | 0.0026 |
| LD Diesel Trucks (60 percent)[9](LDDV) | 2.53 | 1.18 | n/a | n/a | n/a | 0.74 | 230 | 0.018 | 0.0505 | 0.0286 | 0.0148 | 0.00371 | 0.0026 |
| LD Gas Trucks (40 percent) (LDGV) | 9.659 | 0.651 | n/a | n/a | n/a | 0.562 | 330 | 0.119 | 0.0541 | 0.0085 | 0.0151 | 0.00371 | 0.0026 |

| | | | | | | Pollutant Emissions (lbs/well pad) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Equipment | Class of Vehicle | Number of Vehicles | Number of Round Trips Per | Round Trip Distance (mi) | VMT (mi) | CO | NOx | PM10 | PM2.5 | SO2[10] | VOC | CO2 | CH4 | N2O | Formaldehyde | Benzene | Toluene | Xylene |
| Water truck (process water removal) | HDDV | 1 | 2 | 6 | 624 | 23.5 | 8.9 | na | na | 0.01 | 7 | 2,339 | 0.10 | 0.06 | 0.01 | 0.01 | 0.01 | 0.00 |
| Condensate truck (condensate removal) | HDDV | 1 | 3 | 6 | 936 | 35.2 | 13.4 | na | na | 0.02 | 10 | 3,508 | 0.15 | 0.09 | 0.02 | 0.02 | 0.01 | 0.01 |
| light duty vehicles (employee access) - Diesel | LDDV | 1 | 7 | 6 | 2,184 | 12.2 | 5.7 | na | na | na | 4 | 1,107 | 0.09 | 0.24 | 0.14 | 0.07 | 0.02 | 0.01 |
| light duty vehicles (employee access) - Gas | LDGV | 1 | 7 | 6 | 2,184 | 46.5 | 3.1 | na | na | na | 3 | 1,589 | 0.57 | 0.26 | 0.04 | 0.07 | 0.02 | 0.01 |
| **TOTAL (POUNDS)** | | | | | | 70.9 | 28.0 | 0 | 0 | 0.03 | 20 | 8,543 | 0.90 | 0.65 | 0.22 | 0.17 | 0.05 | 0.03 |

Notes:

[1] AP-42, Volume II - Mobile Sources, Appendix H, "Heavy Duty Diesel Trucks" high altitude, "aged" with 50,000 miles service, 2001+ model year (EPA 1995).

[2] AP-42, Volume II - Mobile Sources, Appendix H, "Light Duty Diesel Trucks" high altitude, "aged" with 50,000 miles service, 1990+ model year for NOx, 1984+ model year for CO and HC (EPA 1995).

[3] AP-42, Volume II - Mobile Sources, Appendix H, "Light Duty Gasoline Trucks I" high altitude, "aged" with 50,000 miles service, 1998+ model year (EPA 1995).

[4] PM2.5 emissions assumed equal to PM10 emissions (no PM emission factors avialable from EPA).

[5] Compendium of Greenhouse Gas Emission Methodologies for the Oil and Gas Industry, Table 4-11 (HDDV diesel non-semi truck, LDGT average gasoline car, LDDV large diesel car), CO2 Mobile Source Emission Factors, American Petroleum Institute (2004).

[6] Compendium of Greenhouse Gas Emission Methodologies for the Oil and Gas Industry for CH4, Table 4-9 (HDDV moderate control, LDGT oxidation catalyst, LDDT moderate control), Mobile Source Combustion Emission Factors, Table 4-10 (HDDV Diesel heavy truck, LDGT Gasoline light truck, LDDT Diesel light truck), Default Fuel Economy Factors for Different Types of Mobile Sources, American Petroleum Institute (2004).

[7] Compendium of Greenhouse Gas Emission Methodologies for the Oil and Gas Industry for N2O, Table 4-9 (HDDV moderate control, LDGT oxidation catalyst, LDDT moderate control), Mobile Source Combustion Emission Factors, Table 4-10 (HDDV Diesel heavy truck, LDGT Gasoline light truck, LDDT Diesel light truck), Default Fuel Economy Factors for Different Types of Mobile Sources, American Petroleum Institute (2004).

[8] AP-42, Section 3.3, "Gasoline and Diesel Industrial Engines. Table 3.3-2, "Speciated Organic Compound Emission Factors for Uncontrolled Diesel Engines"

[9] For light duty vehicles (pickup trucks), 60 percent would be diesel-powered, and 40 percent would be gas.

[10] Included in the Pollutant Emissions is the Ultra Low Sulfur adjustment based on 15 ppm Ultra Low Sulfur diesel fuel sulfur content compared to 500 ppm (0.05 percent) #2 diesel fuel sulfur content (15 / 500 = 0.03).

**Table 5.21**

**EMISSIONS SUMMARY 2009**

**Emissions by Source Category (lbs/well)**

| Source Type | CO | $NO_x$ | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | VOCs | Formaldehyde | Benzene | Toluene | Xylene | Ethylbenzene | Hexane | $CO_2$ | $CH_4$ | $N_2O$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Well Pad Construction** | | | | | | | | | | | | | | | |
| General Activity | -- | -- | -- | 368.22 | 55.23 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Road Dust | -- | -- | -- | 4,493.57 | 449.36 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Equipment Exhaust | 104.85 | 342.65 | 33.76 | 33.76 | 1.19 | 28.49 | 0.17 | 0.13 | 0.06 | 0.04 | -- | -- | 23,506 | 1.13 | 0.70 |
| Vehicle Exhaust | 27.76 | 10.30 | 0.01 | -- | -- | 7.64 | 0.02 | 0.02 | 0.0065 | 0.0045 | -- | -- | 2,705 | 0.12 | 0.08 |
| **Subtotal** | **132.61** | **352.95** | **33.77** | **4,895.55** | **505.78** | **36.13** | **0.19** | **0.15** | **0.06** | **0.05** | **0.00** | **0.00** | **26,211.35** | **1.26** | **0.77** |
| **Well Construction** | | | | | | | | | | | | | | | |
| Vehicle Road Dust | -- | -- | -- | 5.46 | 0.55 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Exhaust | 47.22 | 14.40 | 0.00 | 0.00 | 0.05 | 10.26 | 0.14 | 0.09 | 0.03 | 0.02 | -- | -- | 3,687 | 0.34 | 0.34 |
| Drilling Engines - Tier 2 | 7,346.19 | 10,736.74 | 78.82 | 423.82 | 423.82 | 2,825.46 | 10.59 | 8.37 | 3.67 | 2.56 | -- | -- | 1,473,840 | 71.09 | 43.75 |
| *Drilling Engines - Tier 4a (2011)* | *7,346.19* | *7,346.19* | *78.82* | *211.91* | *211.91* | *847.64* | *10.59* | *8.37* | *3.67* | *2.56* | *--* | *--* | *1,473,840* | *71.09* | *43.75* |
| *Drilling Engines - Tier 4b (2015)* | *7,346.19* | *7,346.19* | *78.82* | *62.16* | *62.16* | *395.56* | *10.59* | *8.37* | *3.67* | *2.56* | *--* | *--* | *1,473,840* | *71.09* | *43.75* |
| **Subtotal (with Tier 2 drilling)** | **7,393.41** | **10,751.15** | **78.82** | **429.28** | **424.42** | **2,835.72** | **10.73** | **8.46** | **3.69** | **2.57** | **0.00** | **0.00** | **1,477,526.72** | **71.43** | **44.09** |
| **Completion and Testing** | | | | | | | | | | | | | | | |
| Flaring | 33.60 | 40.00 | 0 | 3.04 | 3.04 | 2.20 | -- | 0.00 | 0.00 | -- | -- | 1.81 | 48,000 | 0.92 | 0.88 |
| Waste Pond Evaporation | -- | -- | -- | -- | -- | 700.00 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Road Dust | -- | -- | -- | 14,044.29 | 1,404.43 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Exhaust | 71.20 | 25.72 | 0.04 | -- | -- | 19.00 | 0.07 | 0.06 | 0.02 | 0.01 | -- | -- | 6,737 | 0.34 | 0.24 |
| Frac Pump Engines | 740.68 | 3,437.28 | 227.30 | 243.94 | 243.94 | 278.76 | 0.92 | 0.72 | 0.32 | 0.22 | -- | -- | 127,512 | 28.31 | -- |
| **Subtotal** | **845.48** | **3,503.00** | **227.58** | **14,291.27** | **1,651.41** | **999.96** | **0.07** | **0.06** | **0.02** | **0.01** | **0.00** | **1.81** | **54,736.92** | **1.26** | **1.12** |
| **CONSTRUCTION TOTAL[1]** | **8,371.49** | **14,607.09** | **340.17** | **19,616.09** | **2,581.60** | **3,871.81** | **10.99** | **8.67** | **3.78** | **2.63** | **0.00** | **1.81** | **1,558,474.99** | **73.95** | **45.99** |
| **Well Production** | | | | | | | | | | | | | | | |
| Heater/Treater | 360.71 | 429.41 | 2.5765 | 32.6353 | 32.6353 | 23.6176 | 0.32 | 0.01 | 0.01 | -- | -- | -- | 515,294 | 9.88 | 9.45 |
| Condensate Tanks | -- | -- | -- | -- | -- | 31,860.00 | -- | 91.80 | -- | -- | -- | 499.50 | -- | -- | -- |
| Gas Generator | 236.87 | 3,048.69 | 0.44 | 0.06 | 0.06 | -- | 41.25 | 0.33 | 0.30 | 0.14 | 0.03 | 0.33 | 82,195 | -- | -- |
| Wind Blown Dust | -- | -- | -- | 1,649.32 | 989.59 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Road Dust | -- | -- | -- | 10,850.98 | 1,085.10 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Exhaust | 70.86 | 28.00 | 0.03 | -- | -- | 20.14 | 0.22 | 0.17 | 0.05 | 0.03 | -- | -- | 8,543 | 0.90 | 0.65 |
| **Subtotal** | **668.43** | **3,506.10** | **3.05** | **12,532.99** | **2,107.38** | **31,903.76** | **41.78** | **92.31** | **0.37** | **0.17** | **0.03** | **499.83** | **606,032.24** | **10.78** | **10.10** |
| **PRODUCTION TOTAL** | **668.43** | **3,506.10** | **3.05** | **12,532.99** | **2,107.38** | **31,903.76** | **41.78** | **92.31** | **0.37** | **0.17** | **0.03** | **499.83** | **606,032.24** | **10.78** | **10.10** |
| **CONSTRUCTION AND PRODUCTION TOTAL** | **9,039.92** | **18,113.20** | **343.22** | **32,149.08** | **4,688.98** | **35,775.57** | **52.78** | **100.98** | **4.15** | **2.81** | **0.03** | **501.64** | **2,164,507.24** | **84.73** | **56.09** |

Notes:
[1]Construction emissions are based on a per well constructed/drilled basis. Construction emissions occur only in the year that a well pad is constructed and associated wells are drilled. All drilling is assumed to be completed in the year of well pad construction.

**Emissions by Source Category (tons/well)**

| Source Type | CO | $NO_x$ | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | VOCs | Formaldehyde | Benzene | Toluene | Xylene | Ethylbenzene | Hexane | $CO_2$ | $CH_4$ | $N_2O$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Well Pad Construction** | | | | | | | | | | | | | | | |
| General Activity | -- | -- | -- | 0.1841 | 0.0276 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Road Dust | -- | -- | -- | 2.2468 | 0.2247 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Equipment Exhaust | 0.0524 | 0.1713 | 0.0169 | 0.0169 | 0.0006 | 0.0142 | 0.0001 | 0.0001 | 0.0000 | 0.0000 | -- | -- | 11.7530 | 0.0006 | 0.0003 |
| Vehicle Exhaust | 0.0139 | 0.0051 | 0.0000 | -- | -- | 0.0038 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | -- | -- | 1.3527 | 0.0001 | 0.0000 |
| **Subtotal** | **0.0663** | **0.1765** | **0.0169** | **2.4478** | **0.2529** | **0.0181** | **0.0001** | **0.0001** | **0.0000** | **0.0000** | **0.0000** | **0.0000** | **13.1057** | **0.0006** | **0.0004** |
| **Well Construction** | | | | | | | | | | | | | | | |
| Vehicle Road Dust | -- | -- | -- | 0.0027 | 0.0003 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Exhaust | 0.0236 | 0.0072 | 0.0000 | 0.0000 | 0.0000 | 0.0051 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | -- | -- | 1.8434 | 0.0002 | 0.0002 |
| Drilling Engines - Tier 2 | 3.6731 | 5.3684 | 0.0394 | 0.2119 | 0.2119 | 1.4127 | 0.0053 | 0.0042 | 0.0018 | 0.0013 | -- | -- | 736.9200 | 0.0355 | 0.0219 |
| *Drilling Engines - Tier 4a (2011)* | *3.6731* | *3.6731* | *0.0394* | *0.1060* | *0.1060* | *0.4238* | *0.0053* | *0.0042* | *0.0018* | *0.0013* | -- | -- | *736.9200* | *0.0355* | *0.0219* |
| *Drilling Engines - Tier 4b (2015)* | *3.6731* | *3.6731* | *0.0394* | *0.0311* | *0.0311* | *0.1978* | *0.0053* | *0.0042* | *0.0018* | *0.0013* | -- | -- | *736.9200* | *0.0355* | *0.0219* |
| **Subtotal (with Tier 2 drilling)** | **3.6967** | **5.3756** | **0.0394** | **0.2146** | **0.2122** | **1.4179** | **0.0054** | **0.0042** | **0.0018** | **0.0013** | **0.0000** | **0.0000** | **738.7634** | **0.0357** | **0.0220** |
| **Completion and Testing** | | | | | | | | | | | | | | | |
| Flaring | 0.0168 | 0.0200 | 0.0001 | 0.0015 | 0.0015 | 0.0011 | -- | 0.0000 | 0.0000 | -- | -- | 0.0009 | 24.0000 | 0.0005 | 0.0004 |
| Waste Pond Evaporation | -- | -- | -- | -- | -- | 0.3500 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Road Dust | -- | -- | -- | 7.0221 | 0.7022 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Exhaust | 0.0356 | 0.0129 | 0.0000 | -- | -- | 0.0095 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | -- | -- | 3.3685 | 0.0002 | 0.0001 |
| Frac Pump Engines | 0.3703 | 1.7186 | 0.1137 | 0.1220 | 0.1220 | 0.1394 | 0.0005 | 0.0004 | 0.0002 | 0.0001 | -- | -- | 63.7560 | 0.0142 | -- |
| **Subtotal** | **0.4227** | **1.7515** | **0.1138** | **7.1456** | **0.8257** | **0.5000** | **0.0000** | **0.0000** | **0.0000** | **0.0000** | **0.0000** | **0.0009** | **27.3685** | **0.0006** | **0.0006** |
| **CONSTRUCTION TOTAL[1]** | **4.1857** | **7.3035** | **0.1701** | **9.8080** | **1.2908** | **1.9359** | **0.0055** | **0.0043** | **0.0019** | **0.0013** | **0.0000** | **0.0009** | **779.2375** | **0.0370** | **0.0230** |
| **Well Production** | | | | | | | | | | | | | | | |
| Heater/Treater | 0.1804 | 0.2147 | 0.0013 | 0.0163 | 0.0163 | 0.0118 | 0.0002 | 0.0000 | 0.0000 | -- | -- | -- | 257.6471 | 0.0049 | 0.0047 |
| Condensate Tanks | -- | -- | -- | -- | -- | 15.9300 | -- | 0.0459 | -- | -- | -- | 0.2498 | -- | -- | -- |
| Gas Generator | 0.1184 | 1.5243 | 0.0002 | 0.0000 | 0.0000 | -- | 0.0206 | 0.0002 | 0.0002 | 0.0001 | 0.0000 | 0.0002 | 41.0975 | -- | -- |
| Wind Blown Dust | -- | -- | -- | 0.8247 | 0.4948 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Road Dust | -- | -- | -- | 5.4255 | 0.5425 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Exhaust | 0.0354 | 0.0140 | 0.0000 | -- | -- | 0.0101 | 0.0001 | 0.0001 | 0.0000 | 0.0000 | -- | -- | 4.2715 | 0.0004 | 0.0003 |
| **Subtotal** | **0.3342** | **1.7531** | **0.0015** | **6.2665** | **1.0537** | **15.9519** | **0.0209** | **0.0462** | **0.0002** | **0.0001** | **0.0000** | **0.2499** | **303.0161** | **0.0054** | **0.0050** |
| **PRODUCTION TOTAL** | **0.3342** | **1.7531** | **0.0015** | **6.2665** | **1.0537** | **15.9519** | **0.0209** | **0.0462** | **0.0002** | **0.0001** | **0.0000** | **0.2499** | **303.0161** | **0.0054** | **0.0050** |
| **CONSTRUCTION AND PRODUCTION TOTAL** | **4.5200** | **9.0566** | **0.1716** | **16.0745** | **2.3445** | **17.8878** | **0.0264** | **0.0505** | **0.0021** | **0.0014** | **0.0000** | **0.2508** | **1082.2536** | **0.0424** | **0.0280** |

Notes:
[1]Construction emissions are based on a per well constructed/drilled basis. Construction emissions occur only in the year that a well pad is constructed and associated wells are drilled. All drilling is assumed to be completed in the year of well pad construction.

Table 5.22

**EMISSIONS SUMMARY - 2011**

**Emissions by Source Category (lbs/well)**

| Source Type | CO | $NO_x$ | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | VOCs | Formaldehyde | Benzene | Toluene | Xylene | Ethylbenzene | Hexane | $CO_2$ | $CH_4$ | $N_2O$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Well Pad Construction** | | | | | | | | | | | | | | | |
| General Activity | -- | -- | -- | 368.22 | 55.23 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Road Dust | -- | -- | -- | 4,493.57 | 449.36 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Equipment Exhaust | 104.85 | 342.65 | 33.76 | 33.76 | 1.19 | 28.49 | 0.17 | 0.13 | 0.06 | 0.04 | -- | -- | 23,506 | 1.13 | 0.70 |
| Vehicle Exhaust | 27.76 | 10.30 | 0.01 | -- | -- | 7.64 | 0.02 | 0.02 | 0.0065 | 0.0045 | -- | -- | 2,705 | 0.12 | 0.08 |
| **Subtotal** | **132.61** | **352.95** | **33.77** | **4,895.55** | **505.78** | **36.13** | **0.19** | **0.15** | **0.06** | **0.05** | **0.00** | **0.00** | **26,211.35** | **1.26** | **0.77** |
| **Well Construction** | | | | | | | | | | | | | | | |
| Vehicle Road Dust | -- | -- | -- | 5.46 | 0.55 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Exhaust | 47.22 | 14.40 | 0.00 | 0.00 | 0.05 | 10.26 | 0.14 | 0.09 | 0.03 | 0.02 | -- | -- | 3,687 | 0.34 | 0.34 |
| *Drilling Engines - Tier 2* | *7,346.19* | *10,736.74* | *78.82* | *423.82* | *423.82* | *2,825.46* | *10.59* | *8.37* | *3.67* | *2.56* | *--* | *--* | *1,473,840* | *71.09* | *43.75* |
| Drilling Engines - Tier 4a (2011) | 7,346.19 | 7,346.19 | 78.82 | 211.91 | 211.91 | 847.64 | 10.59 | 8.37 | 3.67 | 2.56 | -- | -- | 1,473,840 | 71.09 | 43.75 |
| *Drilling Engines - Tier 4b (2015)* | *7,346.19* | *7,346.19* | *78.82* | *62.16* | *62.16* | *395.56* | *10.59* | *8.37* | *3.67* | *2.56* | *--* | *--* | *1,473,840* | *71.09* | *43.75* |
| **Subtotal (with Tier 4a drilling)** | **7,393.41** | **7,360.60** | **78.82** | **217.37** | **212.51** | **857.90** | **10.73** | **8.46** | **3.69** | **2.57** | **0.00** | **0.00** | **1,477,526.72** | **71.43** | **44.09** |
| **Completion and Testing** | | | | | | | | | | | | | | | |
| Flaring | 33.60 | 40.00 | 0 | 3.04 | 3.04 | 2.20 | -- | 0.00 | 0.00 | -- | -- | 1.81 | 48,000 | 0.92 | 0.88 |
| Waste Pond Evaporation | -- | -- | -- | -- | -- | 700.00 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Road Dust | -- | -- | -- | 14,044.29 | 1,404.43 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Exhaust | 71.20 | 25.72 | 0.04 | -- | -- | 19.00 | 0.07 | 0.06 | 0.02 | 0.01 | -- | -- | 6,737 | 0.34 | 0.24 |
| Frac Pump Engines | 740.68 | 3,437.28 | 227.30 | 243.94 | 243.94 | 278.76 | 0.92 | 0.72 | 0.32 | 0.22 | -- | -- | 127,512 | 28.31 | -- |
| **Subtotal** | **845.48** | **3,503.00** | **227.58** | **14,291.27** | **1,651.41** | **999.96** | **0.07** | **0.06** | **0.02** | **0.01** | **0.00** | **1.81** | **54,736.92** | **1.26** | **1.12** |
| **CONSTRUCTION TOTAL[1]** | **8,371.49** | **11,216.54** | **340.17** | **19,404.18** | **2,369.69** | **1,893.99** | **10.99** | **8.67** | **3.78** | **2.63** | **0.00** | **1.81** | **1,558,474.99** | **73.95** | **45.99** |
| **Well Production** | | | | | | | | | | | | | | | |
| Heater/Treater | 360.71 | 429.41 | 2.5765 | 32.6353 | 32.6353 | 23.6176 | 0.32 | 0.01 | 0.01 | -- | -- | -- | 515,294 | 9.88 | 9.45 |
| Condensate Tanks | -- | -- | -- | -- | -- | 31,860.00 | -- | 91.80 | -- | -- | -- | 499.50 | -- | -- | -- |
| Gas Generator | 236.87 | 3,048.69 | 0.44 | 0.06 | 0.06 | -- | 41.25 | 0.33 | 0.30 | 0.14 | 0.03 | 0.33 | 82,195 | -- | -- |
| Wind Blown Dust | -- | -- | -- | 1,649.32 | 989.59 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Road Dust | -- | -- | -- | 10,850.98 | 1,085.10 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Exhaust | 70.86 | 28.00 | 0.03 | -- | -- | 20.14 | 0.22 | 0.17 | 0.05 | 0.03 | -- | -- | 8,543 | 0.90 | 0.65 |
| **Subtotal** | **668.43** | **3,506.10** | **3.05** | **12,532.99** | **2,107.38** | **31,903.76** | **41.78** | **92.31** | **0.37** | **0.17** | **0.03** | **499.83** | **606,032.24** | **10.78** | **10.10** |
| **PRODUCTION TOTAL** | **668.43** | **3,506.10** | **3.05** | **12,532.99** | **2,107.38** | **31,903.76** | **41.78** | **92.31** | **0.37** | **0.17** | **0.03** | **499.83** | **606,032.24** | **10.78** | **10.10** |
| **CONSTRUCTION AND PRODUCTION TOTAL** | **9,039.92** | **14,722.65** | **343.22** | **31,937.17** | **4,477.07** | **33,797.75** | **52.78** | **100.98** | **4.15** | **2.81** | **0.03** | **501.64** | **2,164,507.24** | **84.73** | **56.09** |

Notes:
[1]Construction emissions are based on a per well constructed/drilled basis. Construction emissions occur only in the year that a well pad is constructed and associated wells are drilled. All drilling is assumed to be completed in the year of well pad construction.

**Emissions by Source Category (tons/well)**

| Source Type | CO | $NO_x$ | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | VOCs | Formaldehyde | Benzene | Toluene | Xylene | Ethylbenzene | Hexane | $CO_2$ | $CH_4$ | $N_2O$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Well Pad Construction** | | | | | | | | | | | | | | | |
| General Activity | -- | -- | -- | 0.1841 | 0.0276 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Road Dust | -- | -- | -- | 2.2468 | 0.2247 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Equipment Exhaust | 0.0524 | 0.1713 | 0.0169 | 0.0169 | 0.0006 | 0.0142 | 0.0001 | 0.0001 | 0.0000 | 0.0000 | -- | -- | 11.7530 | 0.0006 | 0.0003 |
| Vehicle Exhaust | 0.0139 | 0.0051 | 0.0000 | -- | -- | 0.0038 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | -- | -- | 1.3527 | 0.0001 | 0.0000 |
| **Subtotal** | **0.0663** | **0.1765** | **0.0169** | **2.4478** | **0.2529** | **0.0181** | **0.0001** | **0.0001** | **0.0000** | **0.0000** | **0.0000** | **0.0000** | **13.1057** | **0.0006** | **0.0004** |
| **Well Construction** | | | | | | | | | | | | | | | |
| Vehicle Road Dust | -- | -- | -- | 0.0027 | 0.0003 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Exhaust | 0.0236 | 0.0072 | 0.0000 | 0.0000 | 0.0000 | 0.0051 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | -- | -- | 1.8434 | 0.0002 | 0.0002 |
| *Drilling Engines - Tier 2* | *3.6731* | *5.3684* | *0.0394* | *0.2119* | *0.2119* | *1.4127* | *0.0053* | *0.0042* | *0.0018* | *0.0013* | *--* | *--* | *736.9200* | *0.0355* | *0.0219* |
| Drilling Engines - Tier 4a (2011) | 3.6731 | 3.6731 | 0.0394 | 0.1060 | 0.1060 | 0.4238 | 0.0053 | 0.0042 | 0.0018 | 0.0013 | -- | -- | 736.9200 | 0.0355 | 0.0219 |
| *Drilling Engines - Tier 4b (2015)* | *3.6731* | *3.6731* | *0.0394* | *0.0311* | *0.0311* | *0.1978* | *0.0053* | *0.0042* | *0.0018* | *0.0013* | *--* | *--* | *736.9200* | *0.0355* | *0.0219* |
| **Subtotal (with Tier 4a drilling)** | **3.6967** | **3.6803** | **0.0394** | **0.1087** | **0.1063** | **0.4289** | **0.0054** | **0.0042** | **0.0018** | **0.0013** | **0.0000** | **0.0000** | **738.7634** | **0.0357** | **0.0220** |
| **Completion and Testing** | | | | | | | | | | | | | | | |
| Flaring | 0.0168 | 0.0200 | 0.0001 | 0.0015 | 0.0015 | 0.0011 | -- | 0.0000 | 0.0000 | -- | -- | 0.0009 | 24.0000 | 0.0005 | 0.0004 |
| Waste Pond Evaporation | -- | -- | -- | -- | -- | 0.3500 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Road Dust | -- | -- | -- | 7.0221 | 0.7022 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Exhaust | 0.0356 | 0.0129 | 0.0000 | -- | -- | 0.0095 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | -- | -- | 3.3685 | 0.0002 | 0.0001 |
| Frac Pump Engines | 0.3703 | 1.7186 | 0.1137 | 0.1220 | 0.1220 | 0.1394 | 0.0005 | 0.0004 | 0.0002 | 0.0001 | -- | -- | 63.7560 | 0.0142 | -- |
| **Subtotal** | **0.4227** | **1.7515** | **0.1138** | **7.1456** | **0.8257** | **0.5000** | **0.0000** | **0.0000** | **0.0000** | **0.0000** | **0.0000** | **0.0009** | **27.3685** | **0.0006** | **0.0006** |
| **CONSTRUCTION TOTAL[1]** | **4.1857** | **5.6083** | **0.1701** | **9.7021** | **1.1848** | **0.9470** | **0.0055** | **0.0043** | **0.0019** | **0.0013** | **0.0000** | **0.0009** | **779.2375** | **0.0370** | **0.0230** |
| **Well Production** | | | | | | | | | | | | | | | |
| Heater/Treater | 0.1804 | 0.2147 | 0.0013 | 0.0163 | 0.0163 | 0.0118 | 0.0002 | 0.0000 | 0.0000 | -- | -- | -- | 257.6471 | 0.0049 | 0.0047 |
| Condensate Tanks | -- | -- | -- | -- | -- | 15.9300 | -- | 0.0459 | -- | -- | -- | 0.2498 | -- | -- | -- |
| Gas Generator | 0.1184 | 1.5243 | 0.0002 | 0.0000 | 0.0000 | -- | 0.0206 | 0.0002 | 0.0002 | 0.0001 | 0.0000 | 0.0002 | 41.0975 | -- | -- |
| Wind Blown Dust | -- | -- | -- | 0.8247 | 0.4948 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Road Dust | -- | -- | -- | 5.4255 | 0.5425 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Exhaust | 0.0354 | 0.0140 | 0.0000 | -- | -- | 0.0101 | 0.0001 | 0.0001 | 0.0000 | 0.0000 | -- | -- | 4.2715 | 0.0004 | 0.0003 |
| **Subtotal** | **0.3342** | **1.7531** | **0.0015** | **6.2665** | **1.0537** | **15.9519** | **0.0209** | **0.0462** | **0.0002** | **0.0001** | **0.0000** | **0.2499** | **303.0161** | **0.0054** | **0.0050** |
| **PRODUCTION TOTAL** | **0.3342** | **1.7531** | **0.0015** | **6.2665** | **1.0537** | **15.9519** | **0.0209** | **0.0462** | **0.0002** | **0.0001** | **0.0000** | **0.2499** | **303.0161** | **0.0054** | **0.0050** |
| **CONSTRUCTION AND PRODUCTION TOTAL** | **4.5200** | **7.3613** | **0.1716** | **15.9686** | **2.2385** | **16.8989** | **0.0264** | **0.0505** | **0.0021** | **0.0014** | **0.0000** | **0.2508** | **1082.2536** | **0.0424** | **0.0280** |

Notes:
[1]Construction emissions are based on a per well constructed/drilled basis. Construction emissions occur only in the year that a well pad is constructed and associated wells are drilled. All drilling is assumed to be completed in the year of well pad construction.

Table 5.23

EMISSION SUMMARY - 2028

Emissions by Source Category (lbs/well)

| Source Type | CO | $NO_x$ | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | VOCs | Formaldehyde | Benzene | Toluene | Xylene | Ethylbenzene | Hexane | $CO_2$ | $CH_4$ | $N_2O$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Well Pad Construction** | | | | | | | | | | | | | | | |
| General Activity | -- | -- | -- | 368.2 | 55.2 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Road Dust | -- | -- | -- | 4493.6 | 449.4 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Equipment Exhaust | 104.8 | 342.6 | 33.8 | 33.8 | 1.2 | 28.5 | 0.17 | 0.13 | 0.06 | 0.04 | -- | -- | 23,506 | 1.13 | 0.70 |
| Vehicle Exhaust | 27.8 | 10.3 | 0.0 | -- | -- | 7.6 | 0.02 | 0.02 | 0.0065 | 0.0045 | -- | -- | 2,705 | 0.12 | 0.08 |
| **Subtotal** | **132.61** | **352.95** | **33.77** | **4,895.55** | **505.78** | **36.13** | **0.19** | **0.15** | **0.06** | **0.05** | **0.00** | **0.00** | **26,211.35** | **1.26** | **0.77** |
| **Well Construction** | | | | | | | | | | | | | | | |
| Vehicle Road Dust | -- | -- | -- | 5.5 | 0.5 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Exhaust | 47.2 | 14.4 | 0.0 | 0.0 | 0.1 | 10.3 | 0.14 | 0.09 | 0.03 | 0.02 | -- | -- | 3,687 | 0.34 | 0.34 |
| *Drilling Engines - Tier 2* | *7,346.2* | *10,736.7* | *78.8* | *423.8* | *423.8* | *2,825.5* | *10.59* | *8.37* | *3.67* | *2.56* | *--* | *--* | *1,473,840* | *71.09* | *43.75* |
| *Drilling Engines - Tier 4a (2011)* | *7,346.2* | *7,346.2* | *78.8* | *211.9* | *211.9* | *847.6* | *10.59* | *8.37* | *3.67* | *2.56* | *--* | *--* | *1,473,840* | *71.09* | *43.75* |
| Drilling Engines - Tier 4b (2015) | 7,346.2 | 7,346.2 | 78.8 | 62.2 | 62.2 | 395.6 | 10.59 | 8.37 | 3.67 | 2.56 | -- | -- | 1,473,840 | 71.09 | 43.75 |
| **Subtotal (with Tier 4b drilling)** | **7,393.41** | **7,360.60** | **78.82** | **67.62** | **62.76** | **405.82** | **10.73** | **8.46** | **3.69** | **2.57** | **0.00** | **0.00** | **1,477,526.72** | **71.43** | **44.09** |
| **Completion and Testing** | | | | | | | | | | | | | | | |
| Flaring | 33.6 | 40.0 | 0.2 | 3.0 | 3.0 | 2.2 | -- | 0.00 | 0.00 | -- | -- | 1.81 | 48,000 | 0.92 | 0.88 |
| Waste Pond Evaporation | -- | -- | -- | -- | -- | 700.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Road Dust | -- | -- | -- | 14,044.3 | 1,404.4 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Exhaust | 71.2 | 25.7 | 0.0 | -- | -- | 19.0 | 0.07 | 0.06 | 0.02 | 0.01 | -- | -- | 6,737 | 0.34 | 0.24 |
| Frac Pump Engines | 740.7 | 3,437.3 | 227.3 | 243.9 | 243.9 | 278.8 | 0.92 | 0.72 | 0.32 | 0.22 | -- | -- | 127,512 | 28.31 | -- |
| **Subtotal** | **845.48** | **3,503.00** | **227.58** | **14,291.27** | **1,651.41** | **999.96** | **0.99** | **0.78** | **0.34** | **0.23** | **0.00** | **1.81** | **182,248.92** | **29.57** | **1.12** |
| **CONSTRUCTION TOTAL[1]** | **8,371.49** | **11,216.54** | **340.17** | **19,254.43** | **2,219.94** | **1,441.92** | **11.91** | **9.39** | **4.10** | **2.85** | **0.00** | **1.81** | **1,685,986.99** | **102.26** | **45.99** |
| **Well Production** | | | | | | | | | | | | | | | |
| Heater/Treater | 360.7 | 429.4 | 2.6 | 32.6 | 32.6 | 23.6 | 0.32 | 0.01 | 0.01 | -- | -- | -- | 515,294 | 9.88 | 9.45 |
| Condensate Tanks | -- | -- | -- | -- | -- | 31,860.0 | -- | 91.80 | -- | -- | -- | 499.50 | -- | -- | -- |
| Gas Generator | 236.9 | 3,048.7 | 0.4 | 0.1 | 0.1 | -- | 41.25 | 0.33 | 0.30 | 0.14 | 0.03 | 0.33 | 82,195 | -- | -- |
| Wind Blown Dust | -- | -- | -- | 1,649.3 | 989.6 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Road Dust | -- | -- | -- | 10,851.0 | 1,085.1 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Exhaust | 70.9 | 28.0 | 0.0 | -- | -- | 20.1 | 0.22 | 0.17 | 0.05 | 0.03 | -- | -- | 8,543 | 0.90 | 0.65 |
| **Subtotal** | **668.43** | **3,506.10** | **3.05** | **12,532.99** | **2,107.38** | **31,903.76** | **41.78** | **92.31** | **0.37** | **0.17** | **0.03** | **499.83** | **606,032.24** | **10.78** | **10.10** |
| **PRODUCTION TOTAL** | **668.43** | **3,506.10** | **3.05** | **12,532.99** | **2,107.38** | **31,903.76** | **41.78** | **92.31** | **0.37** | **0.17** | **0.03** | **499.83** | **606,032.24** | **10.78** | **10.10** |
| **CONSTRUCTION AND PRODUCTION TOTAL** | **9,039.92** | **14,722.65** | **343.22** | **31,787.42** | **4,327.32** | **33,345.67** | **53.69** | **101.70** | **4.47** | **3.03** | **0.03** | **501.64** | **2,292,019.24** | **113.04** | **56.09** |

Notes:
[1]Construction emissions are based on a per well constructed/drilled basis. Construction emissions occur only in the year that a well pad is constructed and associated wells are drilled. All drilling is assumed to be completed in the year of well pad construction.

Emissions by Source Category (tons/well)

| Source Type | CO | $NO_x$ | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | VOCs | Formaldehyde | Benzene | Toluene | Xylene | Ethylbenzene | Hexane | $CO_2$ | $CH_4$ | $N_2O$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Well Pad Construction** | | | | | | | | | | | | | | | |
| General Activity | -- | -- | -- | 0.1841 | 0.0276 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Road Dust | -- | -- | -- | 2.2468 | 0.2247 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Equipment Exhaust | 0.0524 | 0.1713 | 0.0169 | 0.0169 | 0.0006 | 0.0142 | 0.0001 | 0.0001 | 0.0000 | 0.0000 | -- | -- | 11.7530 | 0.0006 | 0.0003 |
| Vehicle Exhaust | 0.0139 | 0.0051 | 0.0000 | -- | -- | 0.0038 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | -- | -- | 1.3527 | 0.0001 | 0.0000 |
| **Subtotal** | **0.0663** | **0.1765** | **0.0169** | **2.4478** | **0.2529** | **0.0181** | **0.0001** | **0.0001** | **0.0000** | **0.0000** | **0.0000** | **0.0000** | **13.1057** | **0.0006** | **0.0004** |
| **Well Construction** | | | | | | | | | | | | | | | |
| Vehicle Road Dust | -- | -- | -- | 0.0027 | 0.0003 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Exhaust | 0.0236 | 0.0072 | 0.0000 | 0.0000 | 0.0000 | 0.0051 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | -- | -- | 1.8434 | 0.0002 | 0.0002 |
| *Drilling Engines - Tier 2* | *3.6731* | *5.3684* | *0.0394* | *0.2119* | *0.2119* | *1.4127* | *0.0053* | *0.0042* | *0.0018* | *0.0013* | -- | -- | *736.9200* | *0.0355* | *0.0219* |
| *Drilling Engines - Tier 4a (2011)* | *3.6731* | *3.6731* | *0.0394* | *0.1060* | *0.1060* | *0.4238* | *0.0053* | *0.0042* | *0.0018* | *0.0013* | -- | -- | *736.9200* | *0.0355* | *0.0219* |
| Drilling Engines - Tier 4b (2015) | 3.6731 | 3.6731 | 0.0394 | 0.0311 | 0.0311 | 0.1978 | 0.0053 | 0.0042 | 0.0018 | 0.0013 | -- | -- | 736.9200 | 0.0355 | 0.0219 |
| **Subtotal (with Tier 4b drilling)** | **3.6967** | **3.6803** | **0.0394** | **0.0338** | **0.0314** | **0.2029** | **0.0054** | **0.0042** | **0.0018** | **0.0013** | **0.0000** | **0.0000** | **738.7634** | **0.0357** | **0.0220** |
| **Completion and Testing** | | | | | | | | | | | | | | | |
| Flaring | 0.0168 | 0.0200 | 0.0001 | 0.0015 | 0.0015 | 0.0011 | -- | 0.0000 | 0.0000 | -- | -- | 0.0009 | 24.0000 | 0.0005 | 0.0004 |
| Waste Pond Evaporation | -- | -- | -- | -- | -- | 0.3500 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Road Dust | -- | -- | -- | 7.0221 | 0.7022 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Exhaust | 0.0356 | 0.0129 | 0.0000 | -- | -- | 0.0095 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | -- | -- | 3.3685 | 0.0002 | 0.0001 |
| Frac Pump Engines | 0.3703 | 1.7186 | 0.1137 | 0.1220 | 0.1220 | 0.1394 | 0.0005 | 0.0004 | 0.0002 | 0.0001 | -- | -- | 63.7560 | 0.0142 | -- |
| **Subtotal** | **0.4227** | **1.7515** | **0.1138** | **7.1456** | **0.8257** | **0.5000** | **0.0005** | **0.0004** | **0.0002** | **0.0001** | **0.0000** | **0.0009** | **91.1245** | **0.0148** | **0.0006** |
| **CONSTRUCTION TOTAL[1]** | **4.1857** | **5.6083** | **0.1701** | **9.6272** | **1.1100** | **0.7210** | **0.0060** | **0.0047** | **0.0020** | **0.0014** | **0.0000** | **0.0009** | **842.9935** | **0.0511** | **0.0230** |
| **Well Production** | | | | | | | | | | | | | | | |
| Heater/Treater | 0.1804 | 0.2147 | 0.0013 | 0.0163 | 0.0163 | 0.0118 | 0.0002 | 0.0000 | 0.0000 | -- | -- | -- | 257.6471 | 0.0049 | 0.0047 |
| Condensate Tanks | -- | -- | -- | -- | -- | 15.9300 | -- | 0.0459 | -- | -- | -- | 0.2498 | -- | -- | -- |
| Gas Generator | 0.1184 | 1.5243 | 0.0002 | 0.0000 | 0.0000 | -- | 0.0206 | 0.0002 | 0.0002 | 0.0001 | 0.0000 | 0.0002 | 41.0975 | -- | -- |
| Wind Blown Dust | -- | -- | -- | 0.8247 | 0.4948 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Road Dust | -- | -- | -- | 5.4255 | 0.5425 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Exhaust | 0.0354 | 0.0140 | 0.0000 | -- | -- | 0.0101 | 0.0001 | 0.0001 | 0.0000 | 0.0000 | -- | -- | 4.2715 | 0.0004 | 0.0003 |
| **Subtotal** | **0.3342** | **1.7531** | **0.0015** | **6.2665** | **1.0537** | **15.9519** | **0.0209** | **0.0462** | **0.0002** | **0.0001** | **0.0000** | **0.2499** | **303.0161** | **0.0054** | **0.0050** |
| **PRODUCTION TOTAL** | **0.3342** | **1.7531** | **0.0015** | **6.2665** | **1.0537** | **15.9519** | **0.0209** | **0.0462** | **0.0002** | **0.0001** | **0.0000** | **0.2499** | **303.0161** | **0.0054** | **0.0050** |
| **CONSTRUCTION AND PRODUCTION TOTAL** | **4.5200** | **7.3613** | **0.1716** | **15.8937** | **2.1637** | **16.6728** | **0.0268** | **0.0509** | **0.0022** | **0.0015** | **0.0000** | **0.2508** | **1146.0096** | **0.0565** | **0.0280** |

Notes:
[1]Construction emissions are based on a per well constructed/drilled basis. Construction emissions occur only in the year that a well pad is constructed and associated wells are drilled. All drilling is assumed to be completed in the year of well pad construction.

**CALPUFF MODELING - EMISSION SUMMARY (2028)**

**Emissions by Source Category[1,2] (g/s/well)**

| Source Type | CO | $NO_x$ | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | VOCs | Benzene | Toluene | Ethylbenzene | Xylene | Hexane | Formaldehyde | $CO_2$ | $CH_4$ | $N_2O$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Well Pad Construction[3]** | | | | | | | | | | | | | | | |
| General Activity | -- | -- | -- | 0.0053 | 0.0008 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Road Dust | -- | -- | -- | 0.0646 | 0.0065 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Equipment Exhaust | 0.0015 | 0.0049 | 0.0005 | 0.0005 | 0.0000 | 0.0004 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | -- | -- | 0.3381 | 0.00002 | 0.0000 |
| Vehicle Exhaust | 0.0004 | 0.0001 | 0.0000 | -- | -- | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | -- | -- | 0.0389 | 0.0000 | 0.0000 |
| **Subtotal** | **0.0019** | **0.0051** | **0.0005** | **0.0704** | **0.0073** | **0.0005** | **0.0000** | **0.0000** | **0.0000** | **0.0000** | **0.0000** | **0.0000** | **0.3770** | **0.0000** | **0.0000** |
| **Well Construction** | | | | | | | | | | | | | | | |
| Vehicle Road Dust | -- | -- | -- | 0.0001 | 0.0000 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Exhaust | 0.0007 | 0.0002 | 0.0000 | 0.0000 | 0.0000 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | -- | -- | 0.0530 | 0.0000 | 0.0000 |
| Drilling Engines - Tier 2 | *0.1057* | *0.1544* | *0.0011* | *0.0061* | *0.0061* | *0.0406* | *0.0002* | *0.0001* | *0.0001* | *0.0000* | *--* | *--* | *21.1986* | *0.0010* | *0.0006* |
| *Drilling Engines - Tier 4a (2011)* | *0.1057* | *0.1057* | *0.0011* | *0.0030* | *0.0030* | *0.0122* | *0.0002* | *0.0001* | *0.0001* | *0.0000* | *--* | *--* | *21.1986* | *0.0010* | *0.0006* |
| *Drilling Engines - Tier 4b (2015)* | 0.1057 | 0.1057 | 0.0011 | 0.0009 | 0.0009 | 0.0057 | 0.0002 | 0.0001 | 0.0001 | 0.0000 | -- | -- | 21.1986 | 0.0010 | 0.0006 |
| **Subtotal (with Tier 4b drilling)** | **0.1063** | **0.1059** | **0.0011** | **0.0010** | **0.0009** | **0.0058** | **0.0002** | **0.0001** | **0.0001** | **0.0000** | **0.0000** | **0.0000** | **21.2516** | **0.0010** | **0.0006** |
| **Completion and Testing** | | | | | | | | | | | | | | | |
| Flaring | 0.0005 | 0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | -- | 0.0000 | 0.0000 | -- | -- | 0.0000 | 0.6904 | 0.0000 | 0.0000 |
| Waste Pond Evaporation | -- | -- | -- | -- | -- | 0.0101 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Road Dust | -- | -- | -- | 0.2020 | 0.0202 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Exhaust | 0.0010 | 0.0004 | 0.0000 | -- | -- | 0.0003 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | -- | -- | 0.0969 | 0.0000 | 0.0000 |
| Frac Pump Engines | 0.0107 | 0.0494 | 0.0033 | 0.0035 | 0.0035 | 0.0040 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | -- | -- | 1.8340 | 0.0004 | -- |
| **Subtotal** | **0.0122** | **0.0504** | **0.0033** | **0.2056** | **0.0238** | **0.0144** | **0.0000** | **0.0000** | **0.0000** | **0.0000** | **0.0000** | **0.0000** | **2.6213** | **0.0004** | **0.0000** |
| **CONSTRUCTION TOTAL** | **0.1204** | **0.1613** | **0.0049** | **0.2769** | **0.0319** | **0.0207** | **0.0002** | **0.0001** | **0.0001** | **0.0000** | **0.0000** | **0.0000** | **24.2500** | **0.0015** | **0.0007** |
| **Well Production** | | | | | | | | | | | | | | | |
| Heater/Treater | 0.0052 | 0.0062 | 0.0000 | 0.0005 | 0.0005 | 0.0003 | 0.0000 | 0.0000 | 0.0000 | -- | -- | -- | 7.4116 | 0.0001 | 0.0001 |
| Condensate Tanks | -- | -- | -- | -- | -- | 0.4583 | -- | 0.0013 | -- | -- | -- | 0.0072 | -- | -- | -- |
| Gas Generator | 0.0034 | 0.0439 | 0.0000 | 0.0000 | 0.0000 | -- | 0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.1822 | -- | -- |
| Wind Blown Dust | -- | -- | -- | 0.0237 | 0.0142 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Road Dust | -- | -- | -- | 0.1561 | 0.0156 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Vehicle Exhaust | 0.0010 | 0.0004 | 0.0000 | -- | -- | 0.0003 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | -- | -- | 0.1229 | 0.0000 | 0.0000 |
| **Subtotal** | **0.0096** | **0.0504** | **0.0000** | **0.1803** | **0.0303** | **0.4589** | **0.0006** | **0.0013** | **0.0000** | **0.0000** | **0.0000** | **0.0072** | **8.7167** | **0.0002** | **0.0001** |
| **PRODUCTION TOTAL** | **0.0096** | **0.0504** | **0.0000** | **0.1803** | **0.0303** | **0.4589** | **0.0006** | **0.0013** | **0.0000** | **0.0000** | **0.0000** | **0.0072** | **8.7167** | **0.0002** | **0.0001** |
| **CONSTRUCTION AND PRODUCTION TOTAL** | **0.1300** | **0.2118** | **0.0049** | **0.4572** | **0.0622** | **0.4796** | **0.0008** | **0.0015** | **0.0001** | **0.0000** | **0.0000** | **0.0072** | **32.9667** | **0.0016** | **0.0008** |

Notes:

[1]Assumes emissions per well.

[2]Emissions are spread over 8,760 hours per year.

[3]Construction emissions occur only in the year that a well pad is constructed and associated wells are drilled. All drilling is assumed to be completed in the year of well pad construction.

| Alternative B (modeled year 2028) | No of Wells Constructed in 2028 | No of Producing Wells in 2028 | Area Source #2 Drill Rig Engines (Construction) Emissions (g/s) CO | $NO_x$ | $SO_2$ | $PM_{10}$ (PMC) | $PM_{2.5}$ (PMF) |
|---|---|---|---|---|---|---|---|
| Coalmont Niobrara | 12 | 234 | 1.268E+00 | 1.268E+00 | 1.360E-02 | 1.073E-02 | 1.073E-02 |
| CBM | 0 | 40 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Granby Anticline | 0 | 16 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| McCallum and South McCallum Infill | 2 | 40 | 2.113E-01 | 2.113E-01 | 2.267E-03 | 1.788E-03 | 1.788E-03 |
| Other North and Middle Park Field Infill | 1 | 20 | 1.057E-01 | 1.057E-01 | 1.134E-03 | 8.941E-04 | 8.941E-04 |
| Rank Wildcats | 1 | 20 | 1.057E-01 | 1.057E-01 | 1.134E-03 | 8.941E-04 | 8.941E-04 |
| **TOTAL** | **16** | **370** | 1.69 | 1.69 | 0.02 | 0.01 | 0.01 |
| **Alternative B (modeled year 2028)** | | | **Area Source #1 Construction of New Wells and Production of Wells Emissions (g/s)** | | | | |
| Coalmont Niobrara (CN) | 12 | 234 | 2.427E+00 | 1.247E+01 | 5.537E-02 | 4.549E+01 | 7.465E+00 |
| CBM (CBMa, CBMb, CBMc) | 0 | 40 | 3.846E-01 | 2.017E+00 | 1.754E-03 | 7.211E+00 | 1.212E+00 |
| CBMa | | | | 9.075E-01 | 7.892E-04 | 3.244E+00 | 5.455E-01 |
| CBMb | | | | 5.402E-01 | 4.698E-04 | 1.931E+00 | 3.247E-01 |
| CBMc | | | | 5.695E-01 | 4.952E-04 | 2.036E+00 | 3.423E-01 |
| Granby Anticline (GA) | 0 | 16 | 1.538E-01 | 8.069E-01 | 7.016E-04 | 2.884E+00 | 4.850E-01 |
| McCallum and South McCallum Infill (MC) | 2 | 40 | 4.141E-01 | 2.129E+00 | 9.272E-03 | 7.763E+00 | 1.275E+00 |
| Other North and Middle Park Field Infill (OTH) | 1 | 20 | 2.070E-01 | 1.064E+00 | 4.636E-03 | 3.881E+00 | 6.373E-01 |
| Rank Wildcats (RW) | 1 | 20 | 2.070E-01 | 1.064E+00 | 4.636E-03 | 3.881E+00 | 6.373E-01 |
| **TOTAL** | **16** | **370** | 3.79 | 21.57 | 0.08 | 78.33 | 12.92 |
| GRAND TOTAL (g/s) | | | 5.48 | 23.26 | 0.10 | 78.34 | 12.94 |
| GRAND TOTAL (tpy) | | | 190.63 | 808.48 | 3.35 | 2723.30 | 449.77 |

| Area Source #2a Construction of New Wells CO | $NO_x$ | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | Area Source #2b Production of Exisiting Wells CO | $NO_x$ | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ |
|---|---|---|---|---|---|---|---|---|---|
| 1.770E-01 | 6.680E-01 | 4.511E-02 | 3.313E+00 | 3.724E-01 | 2.250E+00 | 1.180E+01 | 1.026E-02 | 4.218E+01 | 7.093E+00 |
| 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 3.846E-01 | 2.017E+00 | 1.754E-03 | 7.211E+00 | 1.212E+00 |
| 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 1.538E-01 | 8.069E-01 | 7.016E-04 | 2.884E+00 | 4.850E-01 |
| 2.949E-02 | 1.113E-01 | 7.518E-03 | 5.521E-01 | 6.207E-02 | 3.846E-01 | 2.017E+00 | 1.754E-03 | 7.211E+00 | 1.212E+00 |
| 1.475E-02 | 5.567E-02 | 3.759E-03 | 2.760E-01 | 3.104E-02 | 1.923E-01 | 1.009E+00 | 8.770E-04 | 3.605E+00 | 6.062E-01 |
| 1.475E-02 | 5.567E-02 | 3.759E-03 | 2.760E-01 | 3.104E-02 | 1.923E-01 | 1.009E+00 | 8.770E-04 | 3.605E+00 | 6.062E-01 |
| 0.24 | 0.89 | 0.06 | 4.42 | 0.50 | 3.56 | 18.66 | 0.02 | 66.70 | 11.22 |

| | | |
|---|---|---|
| CBM a | 329,051,182.82 | 45.0% |
| CBM b | 195,874,382.75 | 26.8% |
| CBM c | 206,478,165.68 | 28.2% |

**Alternative B (modeled year 2028)**

| Location | area (m2) | Area Source #1 Construction of New Wells and Production of Wells Emissions (g/s/m2) $SO_2$ | $NO_x$ | $PM_{10}$ (PMC) | $PM_{2.5}$ (PMF) |
|---|---|---|---|---|---|
| Coalmont Niobrara | 423,951,805 | 1.306E-10 | 2.941E-08 | 1.073E-07 | 1.761E-08 |
| Granby Anticline | 232,221,270 | 3.021E-12 | 3.475E-09 | 1.242E-08 | 2.088E-09 |
| McCallum and South McCallum Infill | 426,037,728 | 2.176E-11 | 4.996E-09 | 1.822E-08 | 2.992E-09 |
| Other North and Middle Park Field Infill | 253,604,956 | 1.828E-11 | 4.196E-09 | 1.530E-08 | 2.513E-09 |
| Rank Wildcats | 232,221,270 | 1.996E-11 | 4.583E-09 | 1.671E-08 | 2.744E-09 |
| CBMa | 329,051,182.82 | 2.398E-12 | 2.758E-09 | 9.859E-09 | 1.658E-09 |
| CBMb | 195,874,382.75 | 2.398E-12 | 2.758E-09 | 9.859E-09 | 1.658E-09 |
| CBMc | 206,478,165.68 | 2.398E-12 | 2.758E-09 | 9.859E-09 | 1.658E-09 |
| | | **Area Source #2 Drill Rig Engines (Construction) Emissions (g/s/m2)** | | | |
| Coalmont Niobrara (CN) | 423,951,805 | 3.209E-11 | 2.991E-09 | 2.531E-11 | 2.531E-11 |
| Granby Anticline (GA) | 232,221,270 | 0 | 0 | 0 | 0 |
| McCallum and South McCallum Infill (MC) | 426,037,728 | 5.322E-12 | 4.960E-10 | 4.197E-12 | 4.197E-12 |
| Other North and Middle Park Field Infill (OTH) | 253,604,956 | 4.470E-12 | 4.166E-10 | 3.525E-12 | 3.525E-12 |
| Rank Wildcats (RW) | 232,221,270 | 4.882E-12 | 4.550E-10 | 3.850E-12 | 3.850E-12 |
| CBM (CBMa, CBMb, CBMc) | 731,403,731 | 0 | 0 | 0 | 0 |

| Alternative A | No of Wells Constructed in 2028 | No of Producing Wells in 2028 |
|---|---|---|
| Coalmont Niobrara | 0 | 7 |
| CBM | 0 | 0 |
| Granby Anticline | 0 | 0 |
| McCallum and South McCallum Infill | 0 | 84 |
| Other North and Middle Park Field Infill | 0 | 1 |
| Rank Wildcats | 0 | 17 |
| **TOTAL** | **0** | **109** |

**Table 5.24**

**ALTERNATIVE B - TOTAL EMISSIONS BY YEAR**

**Wells to be Drilled Annually**

| Year | 1 2009 | 2 2010 | 3 2011 | 4 2012 | 5 2013 | 6 2014 | 7 2015 | 8 2016 | 9 2017 | 10 2018 | 11 2019 | 12 2020 | 13 2021 | 14 2022 | 15 2023 | 16 2024 | 17 2025 | 18 2026 | 19 2027 | 20 2028 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wells Drilled Per Year | 14 | 14 | 14 | 14 | 28 | 17 | 17 | 17 | 31 | 16 | 16 | 16 | 30 | 16 | 16 | 16 | 30 | 16 | 16 | 16 |
| Total Producing Wells | 14 | 28 | 42 | 56 | 84 | 101 | 118 | 135 | 166 | 182 | 198 | 214 | 244 | 260 | 276 | 292 | 322 | 338 | 354 | 370 |

**Estimated Construction Emissions (tons/yr)**

| Year | 1 2009 | 2 2010 | 3 2011 | 4 2012 | 5 2013 | 6 2014 | 7 2015 | 8 2016 | 9 2017 | 10 2018 | 11 2019 | 12 2020 | 13 2021 | 14 2022 | 15 2023 | 16 2024 | 17 2025 | 18 2026 | 19 2027 | 20 2028 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tier 2 Drill Rig Engines (%) | 100% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Tier 4a Drill Rig Engines (%) | 0% | 0% | 100% | 100% | 100% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Tier 4b Drill Rig Engines (%) | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | | | | | | | | | | | | | | | | | | | |
| CO | 59 | 59 | 59 | 59 | 117 | 71 | 71 | 71 | 130 | 67 | 67 | 67 | 126 | 67 | 67 | 67 | 126 | 67 | 67 | 67 |
| NOx | 102 | 102 | 79 | 79 | 157 | 95 | 95 | 95 | 174 | 90 | 90 | 90 | 168 | 90 | 90 | 90 | 168 | 90 | 90 | 90 |
| SO2 | 2 | 2 | 2 | 2 | 5 | 3 | 3 | 3 | 5 | 3 | 3 | 3 | 5 | 3 | 3 | 3 | 5 | 3 | 3 | 3 |
| PM10 | 137 | 137 | 136 | 136 | 272 | 165 | 164 | 164 | 298 | 154 | 154 | 154 | 289 | 154 | 154 | 154 | 289 | 154 | 154 | 154 |
| PM2.5 | 18 | 18 | 17 | 17 | 33 | 20 | 19 | 19 | 34 | 18 | 18 | 18 | 33 | 18 | 18 | 18 | 33 | 18 | 18 | 18 |
| VOC | 27 | 27 | 13 | 13 | 27 | 16 | 12 | 12 | 22 | 12 | 12 | 12 | 22 | 12 | 12 | 12 | 22 | 12 | 12 | 12 |
| Formaldehyde | 0.08 | 0.08 | 0.08 | 0.08 | 0.15 | 0.09 | 0.10 | 0.10 | 0.18 | 0.10 | 0.10 | 0.10 | 0.18 | 0.10 | 0.10 | 0.10 | 0.18 | 0.10 | 0.10 | 0.10 |
| Benzene | 0.06 | 0.06 | 0.06 | 0.06 | 0.12 | 0.07 | 0.08 | 0.08 | 0.15 | 0.08 | 0.08 | 0.08 | 0.14 | 0.08 | 0.08 | 0.08 | 0.14 | 0.08 | 0.08 | 0.08 |
| Toluene | 0.03 | 0.03 | 0.03 | 0.03 | 0.05 | 0.03 | 0.03 | 0.03 | 0.06 | 0.03 | 0.03 | 0.03 | 0.06 | 0.03 | 0.03 | 0.03 | 0.06 | 0.03 | 0.03 | 0.03 |
| Xylene | 0.02 | 0.02 | 0.02 | 0.02 | 0.04 | 0.02 | 0.02 | 0.02 | 0.04 | 0.02 | 0.02 | 0.02 | 0.04 | 0.02 | 0.02 | 0.02 | 0.04 | 0.02 | 0.02 | 0.02 |
| Ethylbenzene | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Hexane | 0.01 | 0.01 | 0.01 | 0.01 | 0.03 | 0.02 | 0.02 | 0.02 | 0.03 | 0.01 | 0.01 | 0.01 | 0.03 | 0.01 | 0.01 | 0.01 | 0.03 | 0.01 | 0.01 | 0.01 |
| Total HAPs | 0.20 | 0.20 | 0.20 | 0.20 | 0.39 | 0.24 | 0.26 | 0.26 | 0.47 | 0.24 | 0.24 | 0.24 | 0.45 | 0.24 | 0.24 | 0.24 | 0.45 | 0.24 | 0.24 | 0.24 |
| CO2 | 10,909 | 10,909 | 10,909 | 10,909 | 21,819 | 13,247 | 14,331 | 14,331 | 26,133 | 13,488 | 13,488 | 13,488 | 25,290 | 13,488 | 13,488 | 13,488 | 25,290 | 13,488 | 13,488 | 13,488 |
| CH4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 1 |
| N2O | 0.32 | 0.32 | 0.32 | 0.32 | 0.64 | 0.39 | 0.39 | 0.39 | 0.71 | 0.37 | 0.37 | 0.37 | 0.69 | 0.37 | 0.37 | 0.37 | 0.69 | 0.37 | 0.37 | 0.37 |

**Estimated Production Emissions (tons/yr)**

| Year | 1 2009 | 2 2010 | 3 2011 | 4 2012 | 5 2013 | 6 2014 | 7 2015 | 8 2016 | 9 2017 | 10 2018 | 11 2019 | 12 2020 | 13 2021 | 14 2022 | 15 2023 | 16 2024 | 17 2025 | 18 2026 | 19 2027 | 20 2028 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO | 5 | 9 | 14 | 19 | 28 | 34 | 39 | 45 | 55 | 61 | 66 | 72 | 82 | 87 | 92 | 98 | 108 | 113 | 118 | 124 |
| NOx | 25 | 49 | 74 | 98 | 147 | 177 | 207 | 237 | 291 | 319 | 347 | 375 | 428 | 456 | 484 | 512 | 564 | 593 | 621 | 649 |
| SO2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| PM10 | 88 | 175 | 263 | 351 | 526 | 633 | 739 | 846 | 1,040 | 1,141 | 1,241 | 1,341 | 1,529 | 1,629 | 1,730 | 1,830 | 2,018 | 2,118 | 2,218 | 2,319 |
| PM2.5 | 15 | 30 | 44 | 59 | 89 | 106 | 124 | 142 | 175 | 192 | 209 | 225 | 257 | 274 | 291 | 308 | 339 | 356 | 373 | 390 |
| VOC | 223 | 447 | 670 | 893 | 1,340 | 1,611 | 1,882 | 2,154 | 2,648 | 2,903 | 3,158 | 3,414 | 3,892 | 4,147 | 4,403 | 4,658 | 5,137 | 5,392 | 5,647 | 5,902 |
| Formaldehyde | 0.29 | 0.58 | 0.88 | 1.17 | 1.75 | 2.11 | 2.47 | 2.82 | 3.47 | 3.80 | 4.14 | 4.47 | 5.10 | 5.43 | 5.77 | 6.10 | 6.73 | 7.06 | 7.40 | 7.73 |
| Benzene | 0.65 | 1.29 | 1.94 | 2.58 | 3.88 | 4.66 | 5.45 | 6.23 | 7.66 | 8.40 | 9.14 | 9.88 | 11.26 | 12.00 | 12.74 | 13.48 | 14.86 | 15.60 | 16.34 | 17.08 |
| Toluene | 0.00 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 | 0.04 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 | 0.06 | 0.06 | 0.07 | 0.07 |
| Xylene | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| Ethylbenzene | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 |
| Hexane | 3.50 | 7.00 | 10.50 | 14.00 | 20.99 | 25.24 | 29.49 | 33.74 | 41.49 | 45.48 | 49.48 | 53.48 | 60.98 | 64.98 | 68.98 | 72.98 | 80.47 | 84.47 | 88.47 | 92.47 |
| Total HAPs | 4.44 | 8.88 | 13.32 | 17.77 | 26.65 | 32.04 | 37.44 | 42.83 | 52.66 | 57.74 | 62.82 | 67.89 | 77.41 | 82.48 | 87.56 | 92.64 | 102.15 | 107.23 | 112.31 | 117.38 |
| CO2 | 4,242 | 8,484 | 12,727 | 16,969 | 25,453 | 30,605 | 35,756 | 40,907 | 50,301 | 55,149 | 59,997 | 64,845 | 73,936 | 78,784 | 83,632 | 88,481 | 97,571 | 102,419 | 107,268 | 112,116 |
| CH4 | 0.08 | 0.15 | 0.23 | 0.30 | 0.45 | 0.54 | 0.64 | 0.73 | 0.89 | 0.98 | 1.07 | 1.15 | 1.31 | 1.40 | 1.49 | 1.57 | 1.73 | 1.82 | 1.91 | 1.99 |
| N2O | 0.07 | 0.14 | 0.21 | 0.28 | 0.42 | 0.51 | 0.60 | 0.68 | 0.84 | 0.92 | 1.00 | 1.08 | 1.23 | 1.31 | 1.39 | 1.47 | 1.63 | 1.71 | 1.79 | 1.87 |

**Estimated Total Emissions (tons/yr)**

| Year | 1 2009 | 2 2010 | 3 2011 | 4 2012 | 5 2013 | 6 2014 | 7 2015 | 8 2016 | 9 2017 | 10 2018 | 11 2019 | 12 2020 | 13 2021 | 14 2022 | 15 2023 | 16 2024 | 17 2025 | 18 2026 | 19 2027 | 20 2028 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO | 63 | 68 | 73 | 77 | 145 | 105 | 111 | 116 | 185 | 128 | 133 | 138 | 207 | 154 | 159 | 165 | 233 | 180 | 185 | 191 |
| NOx | 127 | 151 | 152 | 177 | 304 | 272 | 302 | 332 | 465 | 409 | 437 | 465 | 596 | 546 | 574 | 602 | 733 | 682 | 710 | 738 |
| SO2 | 2 | 2 | 2 | 2 | 5 | 3 | 3 | 3 | 6 | 3 | 3 | 3 | 5 | 3 | 3 | 3 | 6 | 3 | 3 | 3 |
| PM10 | 225 | 313 | 399 | 487 | 798 | 798 | 903 | 1,010 | 1,339 | 1,295 | 1,395 | 1,495 | 1,818 | 1,783 | 1,884 | 1,984 | 2,307 | 2,272 | 2,372 | 2,473 |
| PM2.5 | 33 | 48 | 61 | 76 | 122 | 127 | 143 | 161 | 209 | 210 | 226 | 243 | 290 | 292 | 309 | 325 | 373 | 374 | 391 | 408 |
| VOC | 250 | 474 | 683 | 907 | 1,366 | 1,627 | 1,895 | 2,166 | 2,670 | 2,915 | 3,170 | 3,425 | 3,914 | 4,159 | 4,414 | 4,669 | 5,158 | 5,403 | 5,659 | 5,914 |
| Formaldehyde | 0.37 | 0.66 | 0.95 | 1.25 | 1.91 | 2.20 | 2.57 | 2.92 | 3.65 | 3.90 | 4.23 | 4.57 | 5.28 | 5.53 | 5.86 | 6.20 | 6.91 | 7.16 | 7.49 | 7.83 |
| Benzene | 0.71 | 1.35 | 2.00 | 2.65 | 4.00 | 4.74 | 5.53 | 6.31 | 7.81 | 8.48 | 9.21 | 9.95 | 11.40 | 12.08 | 12.81 | 13.55 | 15.00 | 15.68 | 16.41 | 17.15 |
| Toluene | 0.03 | 0.03 | 0.03 | 0.04 | 0.07 | 0.05 | 0.06 | 0.06 | 0.09 | 0.07 | 0.07 | 0.07 | 0.11 | 0.08 | 0.08 | 0.09 | 0.12 | 0.09 | 0.10 | 0.10 |
| Xylene | 0.02 | 0.02 | 0.02 | 0.02 | 0.04 | 0.03 | 0.03 | 0.04 | 0.06 | 0.04 | 0.04 | 0.04 | 0.06 | 0.05 | 0.05 | 0.05 | 0.07 | 0.05 | 0.05 | 0.05 |
| Ethylbenzene | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 |
| Hexane | 3.51 | 7.01 | 10.51 | 14.01 | 21.02 | 25.26 | 29.51 | 33.75 | 41.51 | 45.50 | 49.50 | 53.50 | 61.01 | 64.99 | 68.99 | 72.99 | 80.50 | 84.49 | 88.48 | 92.48 |
| Total HAPs | 4.64 | 9.08 | 13.52 | 17.96 | 27.04 | 32.28 | 37.69 | 43.08 | 53.13 | 57.98 | 63.06 | 68.13 | 77.86 | 82.73 | 87.80 | 92.88 | 102.60 | 107.47 | 112.55 | 117.62 |
| CO2 | 15,152 | 19,394 | 23,636 | 27,878 | 47,272 | 43,852 | 50,087 | 55,238 | 76,433 | 68,637 | 73,485 | 78,333 | 99,226 | 92,272 | 97,120 | 101,969 | 122,861 | 115,907 | 120,756 | 125,604 |
| CH4 | 0.59 | 0.67 | 0.74 | 0.82 | 1.49 | 1.17 | 1.51 | 1.60 | 2.48 | 1.80 | 1.88 | 1.97 | 2.85 | 2.22 | 2.31 | 2.39 | 3.27 | 2.64 | 2.73 | 2.81 |
| N2O | 0.39 | 0.46 | 0.53 | 0.60 | 1.07 | 0.90 | 0.99 | 1.07 | 1.55 | 1.29 | 1.37 | 1.45 | 1.92 | 1.68 | 1.76 | 1.84 | 2.32 | 2.07 | 2.16 | 2.24 |

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